Vol. 19.—No. 111. JANUARY, 1939. Price 2/-. [Subscription 24/- per annum post free.]

METALLURGIA

THE BRITISH JOURNAL OF METALS

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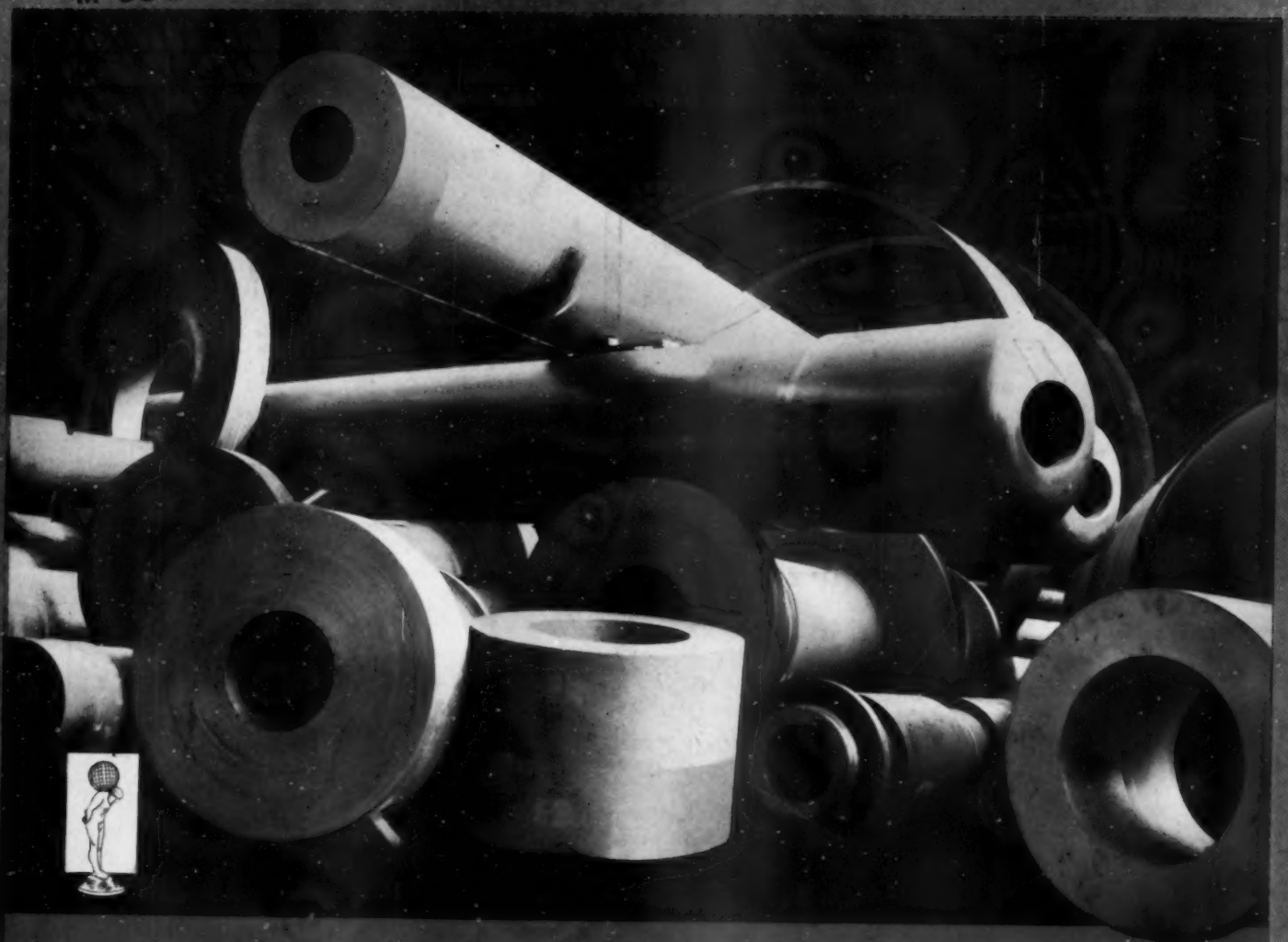

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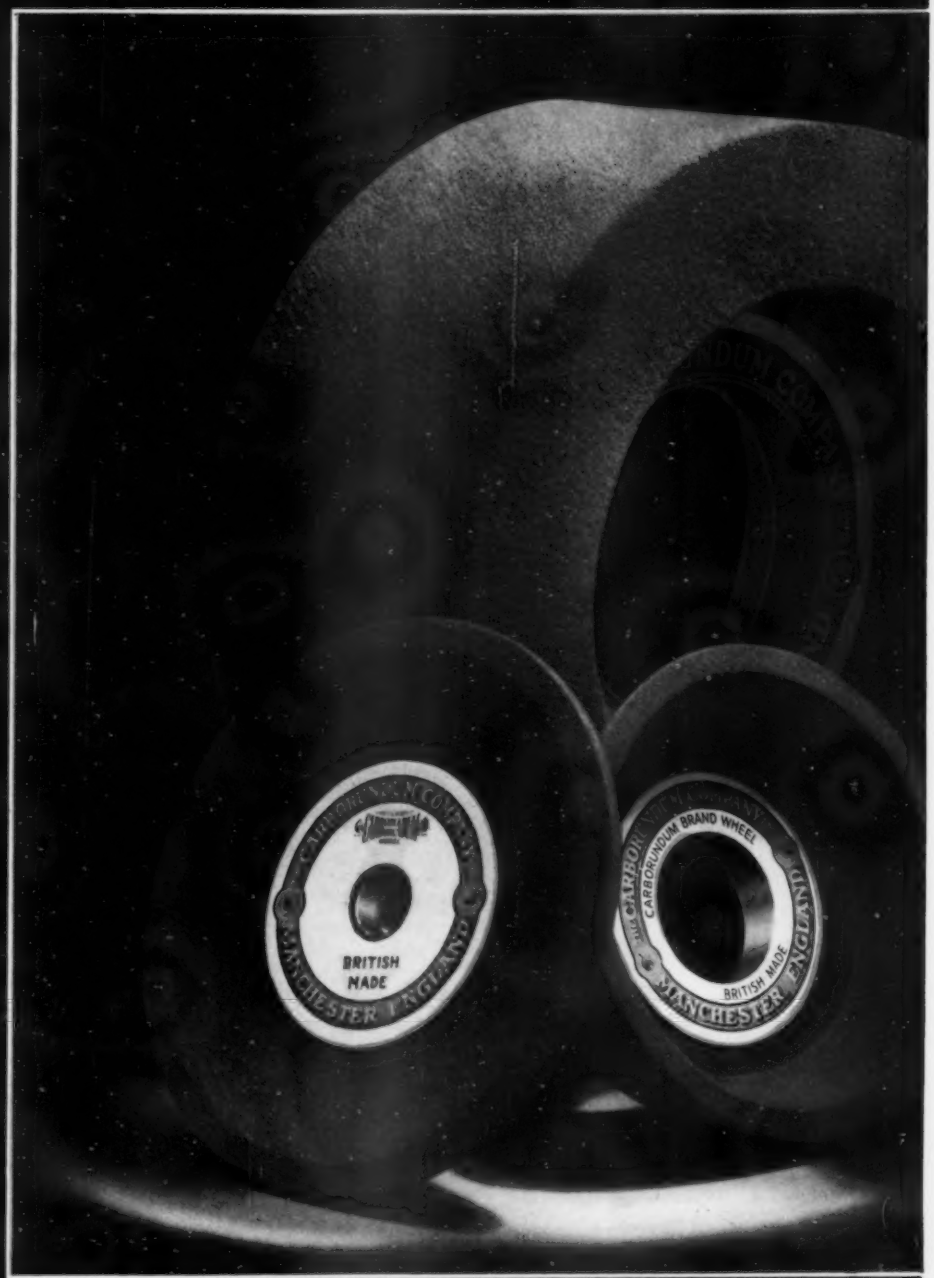

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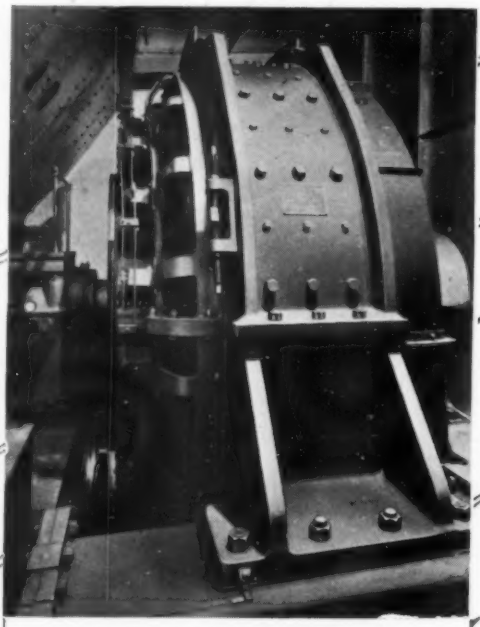
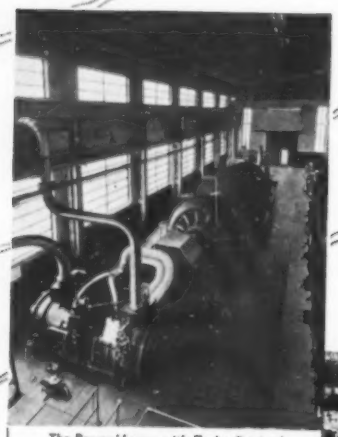
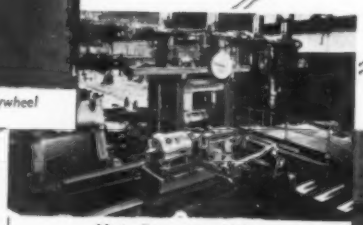


2,900 hp. D.C. Roughing Mill Motor.

Yet another important contribution towards the increased efficiency of well-known works throughout the country is the "Metrovick" Electrical Equipment of the new Sheet Bar Mill at the Albion Works of the Briton Ferry Steel Company.



The Power House, with Turbo-flywheel Generator Set.



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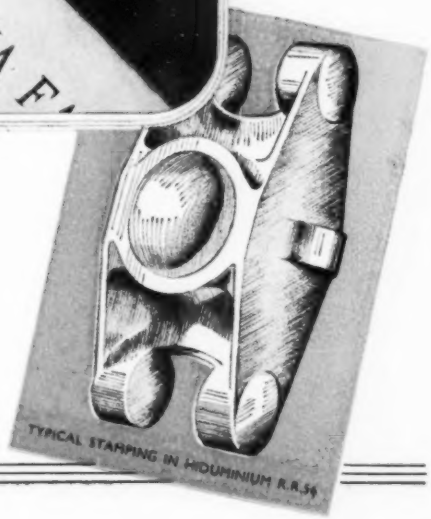

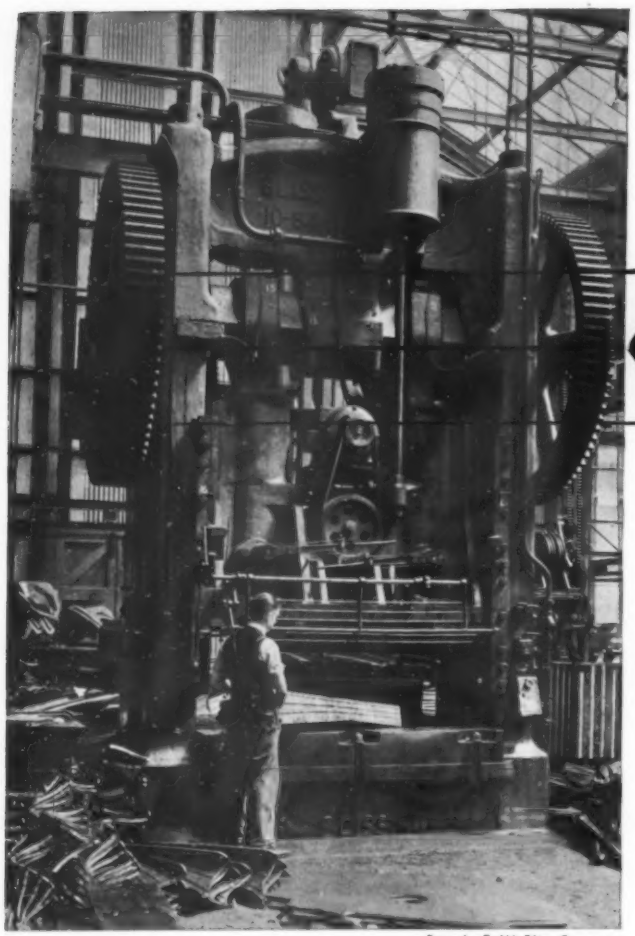

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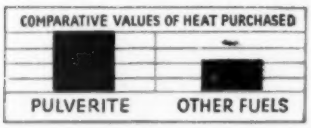
the modern industrial fuel

A SCIENTIFICALLY PREPARED FUEL for use in all types of BOILERS AND METALLURGICAL FURNACES



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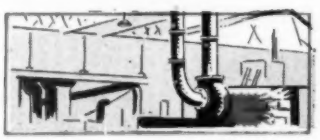

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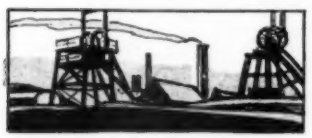

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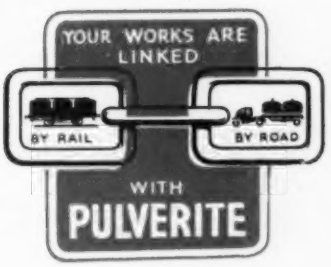

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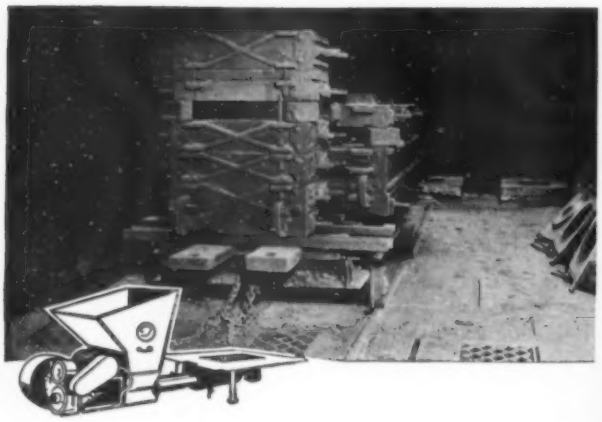

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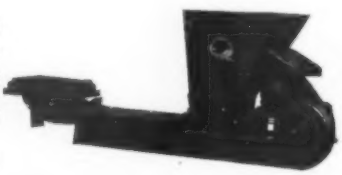

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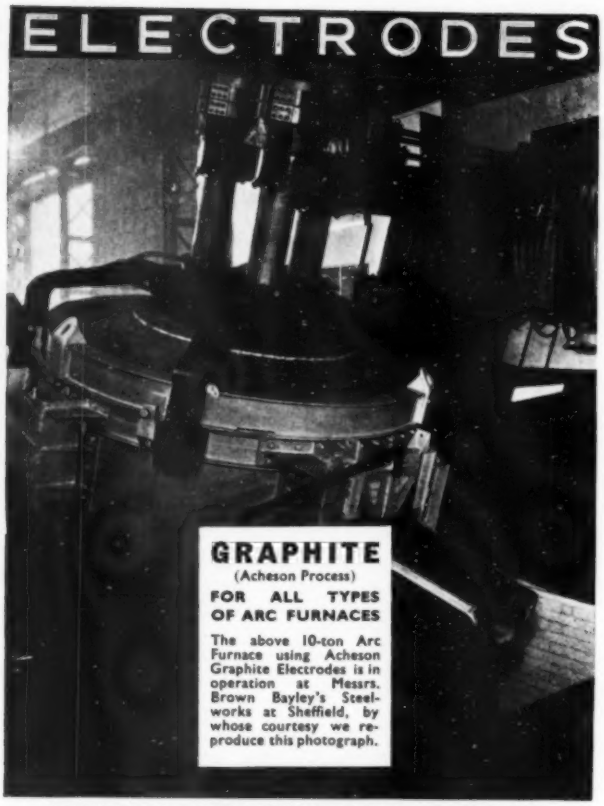

GRAPHITE
(Acheson Process)
FOR ALL TYPES OF ARC FURNACES
The above 10-ton Arc Furnace using Acheson Graphite Electrodes is in operation at Messrs. Brown Bayley's Steelworks at Sheffield, by whose courtesy we reproduce this photograph.

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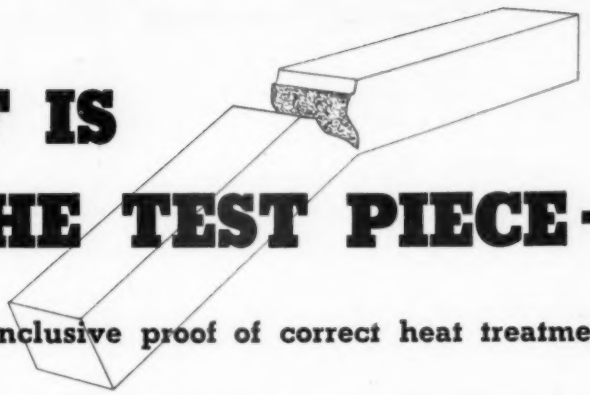
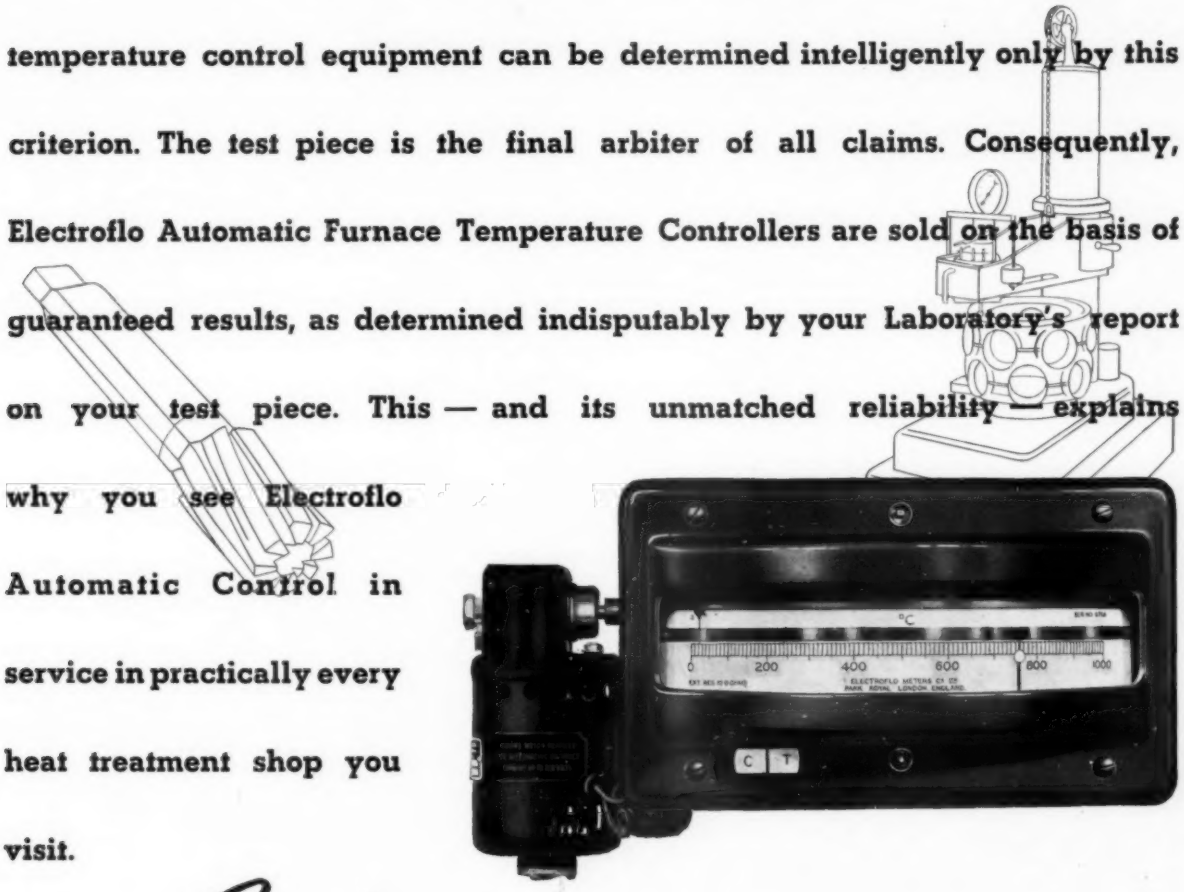
THE PROOF IS IN THE TEST PIECE——



The only conclusive proof of correct heat treatment is the final condition of the treated product. Therefore, the efficiency of furnace temperature control equipment can be determined intelligently only by this criterion. The test piece is the final arbiter of all claims. Consequently, Electroflo Automatic Furnace Temperature Controllers are sold on the basis of guaranteed results, as determined indisputably by your Laboratory's report on your test piece. This — and its unmatched reliability — explains why you see Electroflo Automatic Control in service in practically every heat treatment shop you visit.



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AUTOMATIC TEMPERATURE CONTROL

for guaranteed results with the maximum heat economy

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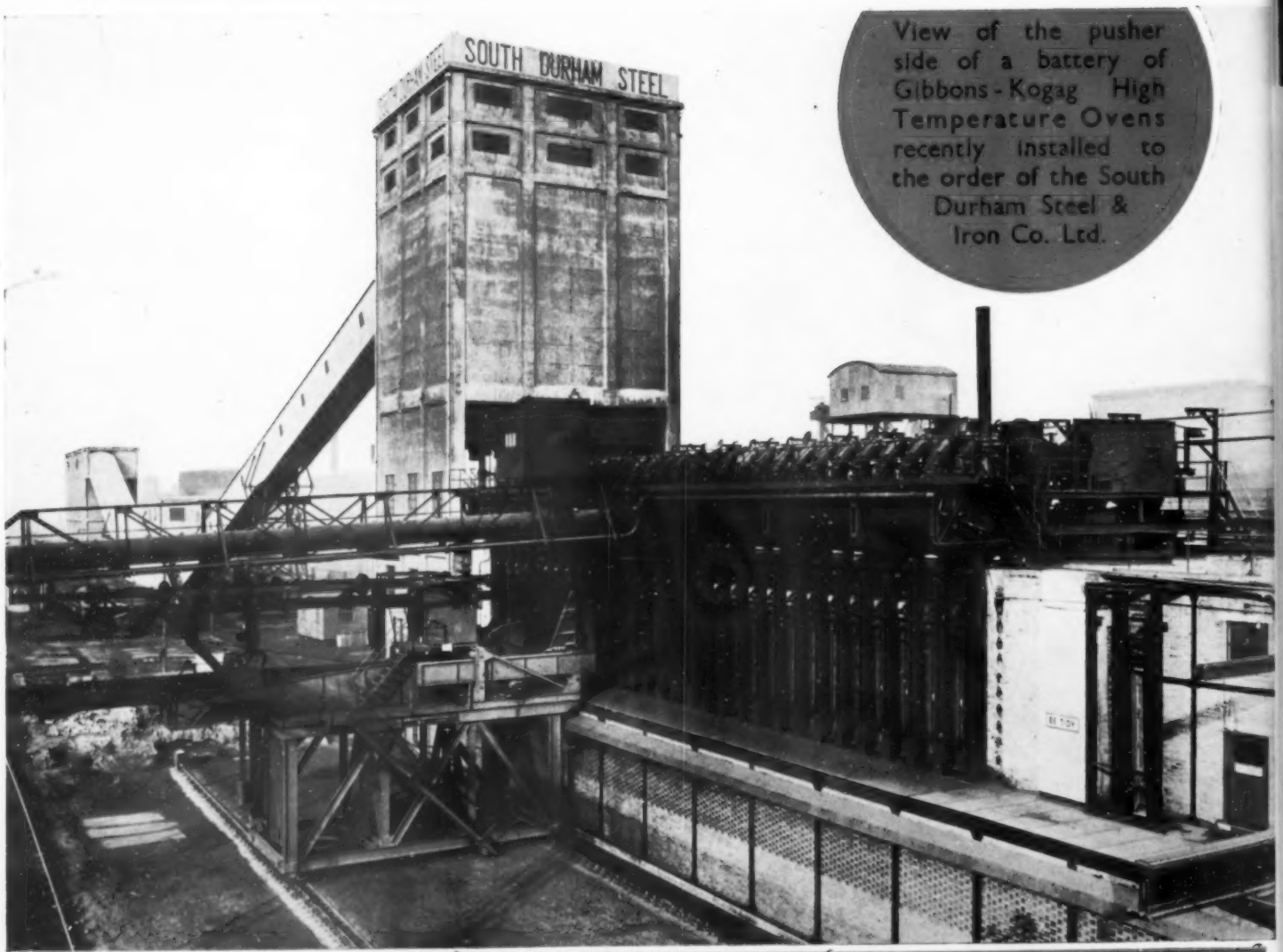
GIBBONS-KOGAG HIGH TEMPERATURE COKE OVENS AND BY-PRODUCT PLANT

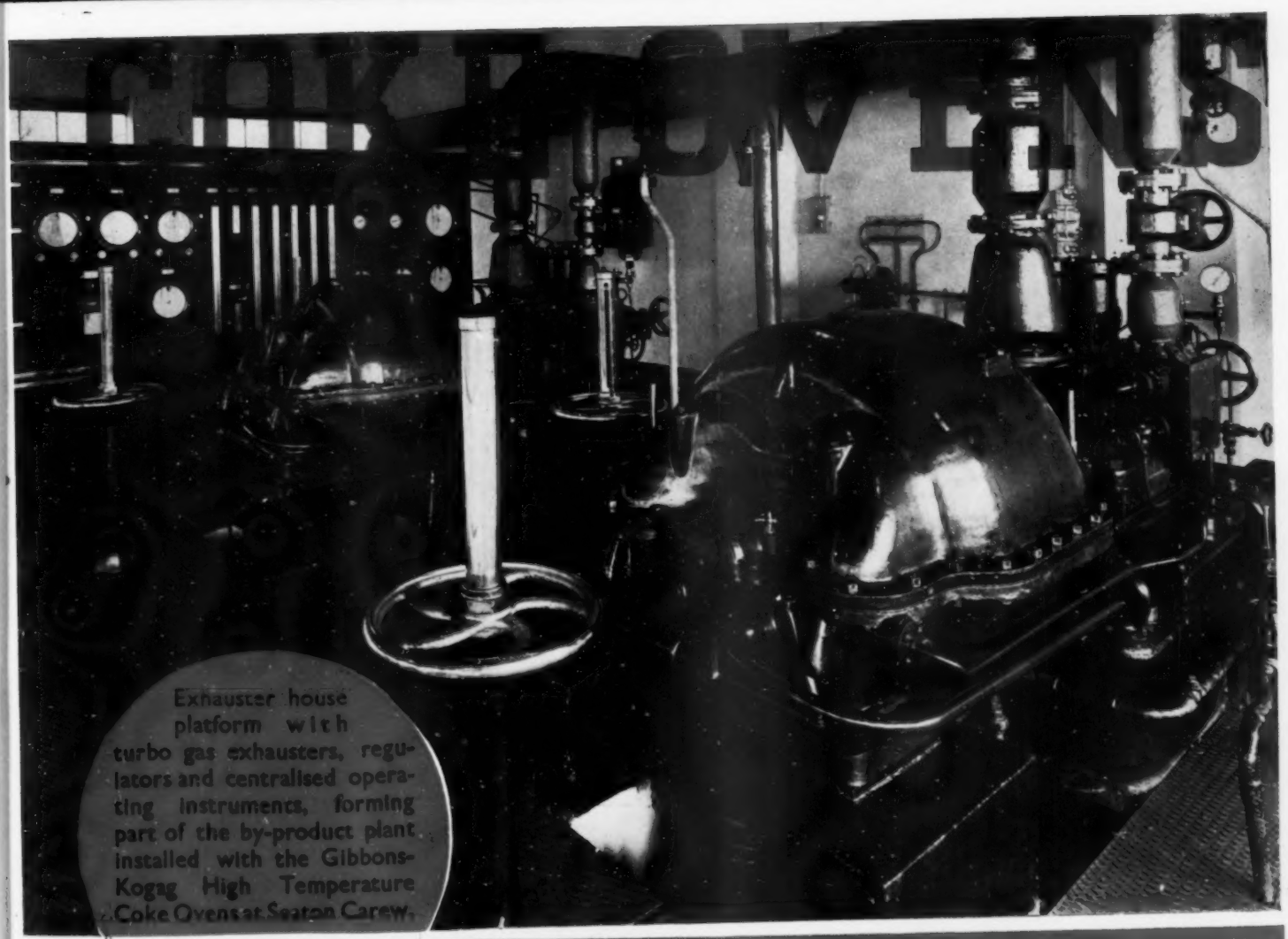
GIBBONS



View of the pusher side of a battery of Gibbons-Kogag High Temperature Ovens recently installed to the order of the South Durham Steel & Iron Co. Ltd.

GIBBONS BROS. LIMITED,

KOGAG



Exhauster house platform with turbo gas exhausters, regulators and centralised operating instruments, forming part of the by-product plant installed with the Gibbons-Kogag High Temperature Coke Ovens at Seaton Carew.

DUDLEY, WORCESTER . . .

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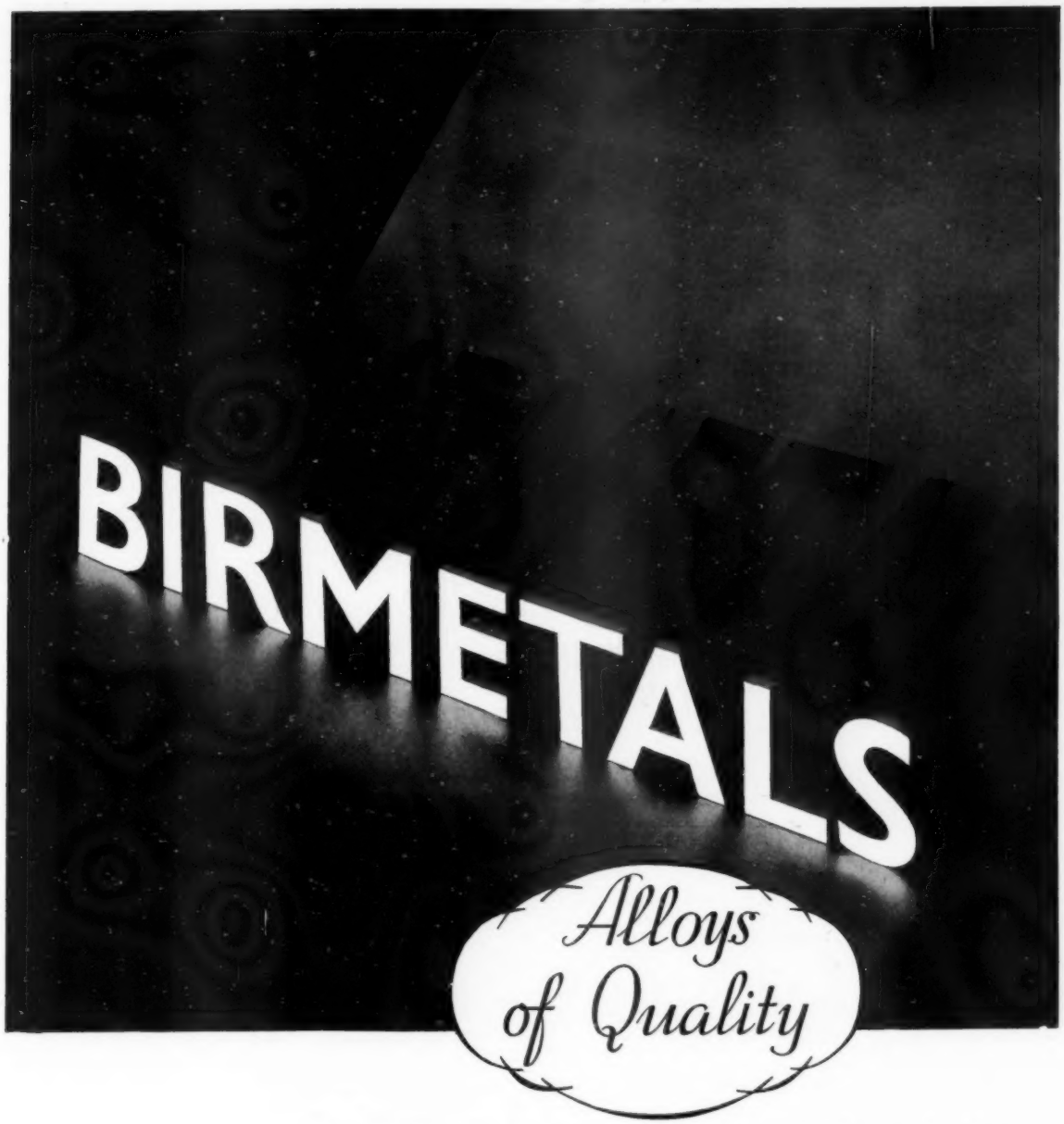

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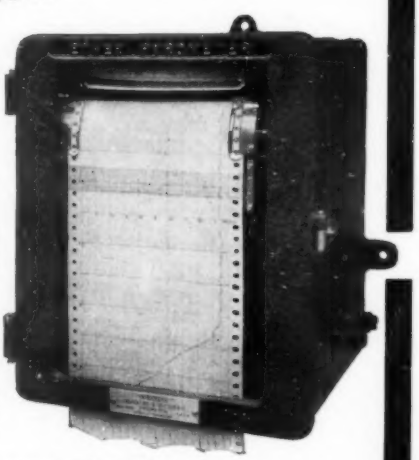

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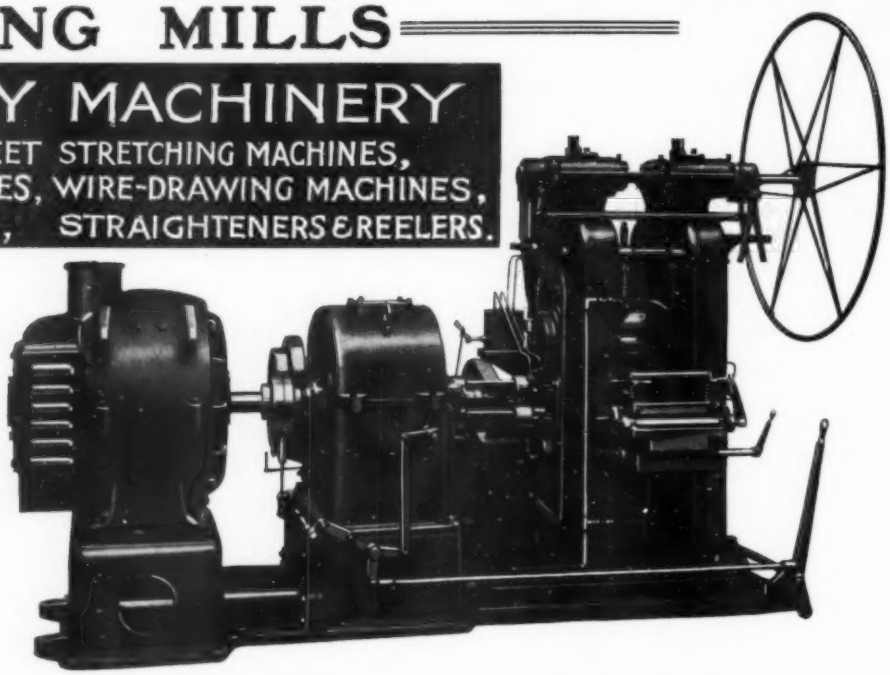

Standard four-high cold-strip mill for both steel and non-ferrous metals. This design is regularly supplied in all sizes.

Especially economical for finishing light gauge strip in any width.

Rolling speeds 100—400 f.p.m. Also supplied as Reversing Mills and in Tandem Train for continuous rolling.

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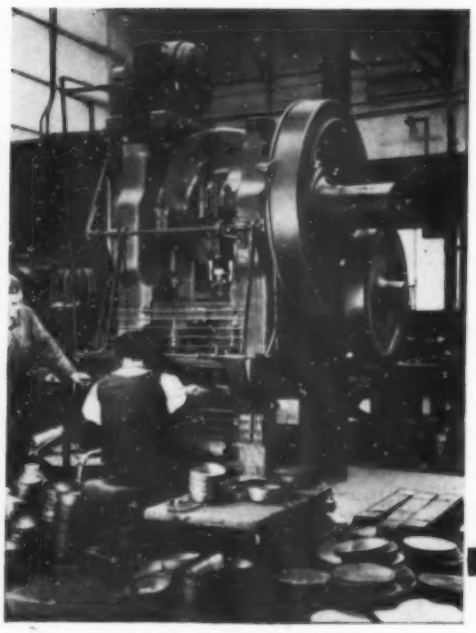

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ALCLAD & MAGNESIUM ALLOY PRESSINGS
ASSEMBLED ENGINEERING UNITS ANODISED,
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'Grams :
"PERBARMET,
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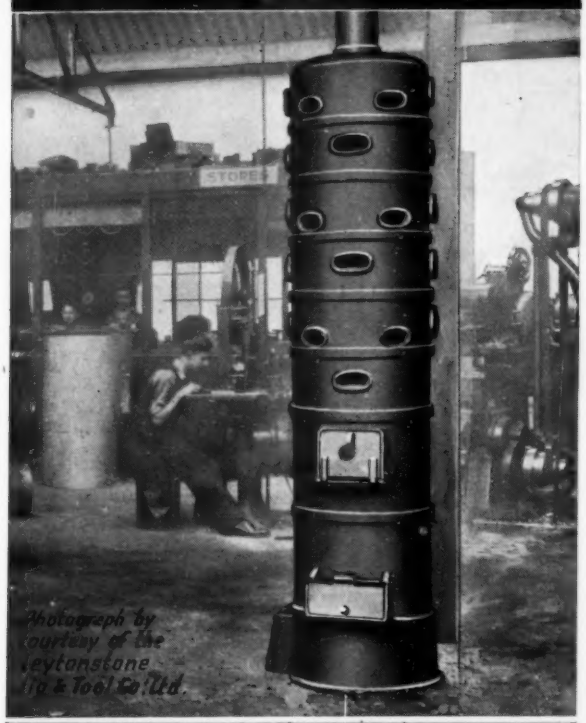
Effective provision shall be made for securing and maintaining a reasonable temperature in each workroom.

(EXTRACT FROM THE FACTORIES ACT 1937)



Photograph by courtesy of the Leytonstone Tin & Tool Co. Ltd.

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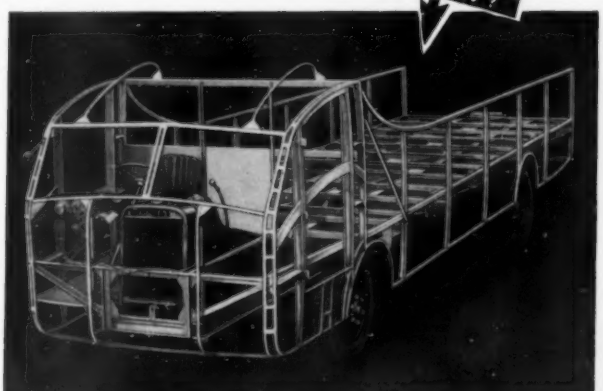
SLOW COMBUSTION
STOVES

Burns the cheapest kind of slack and needs little attention. Enormous heating surfaces. Sectional construction. Built in three sizes with capacities of 30,000, 60,000 and 120,000 cubic feet. Delivery from stock.
Note that we will send a Stove on trial, subject to return if not satisfactory.

JOSHUA BIGWOOD & SON LTD
WOLVERHAMPTON.

May we solve your problem as we solved ours?

We wanted to "go to great lengths" in our deliveries . . . economically and with greatest possible speed. We append details of how our heavy problems became lightened—of how, with the "constructive" co-operation of Messrs. Jensen Motors Ltd., of West Bromwich, the vehicle illustrated below was evolved. That it is revolutionary, that it solves the problem of big loads on a vehicle below the 50 cwt. unladen class, that it provides the "30 m.p.h." objective, and a whole host of other unique features, will be instantly apparent to those who read our fully illustrated descriptive Book—shortly going to press. Write us for an advance copy.



WHY NOT THIS?

Illustration shows complete vehicle "weight 37 cwts.," prior to sheeting of cab and body.

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SHEETS & SECTIONS
IN ALUMINIUM ALLOYS

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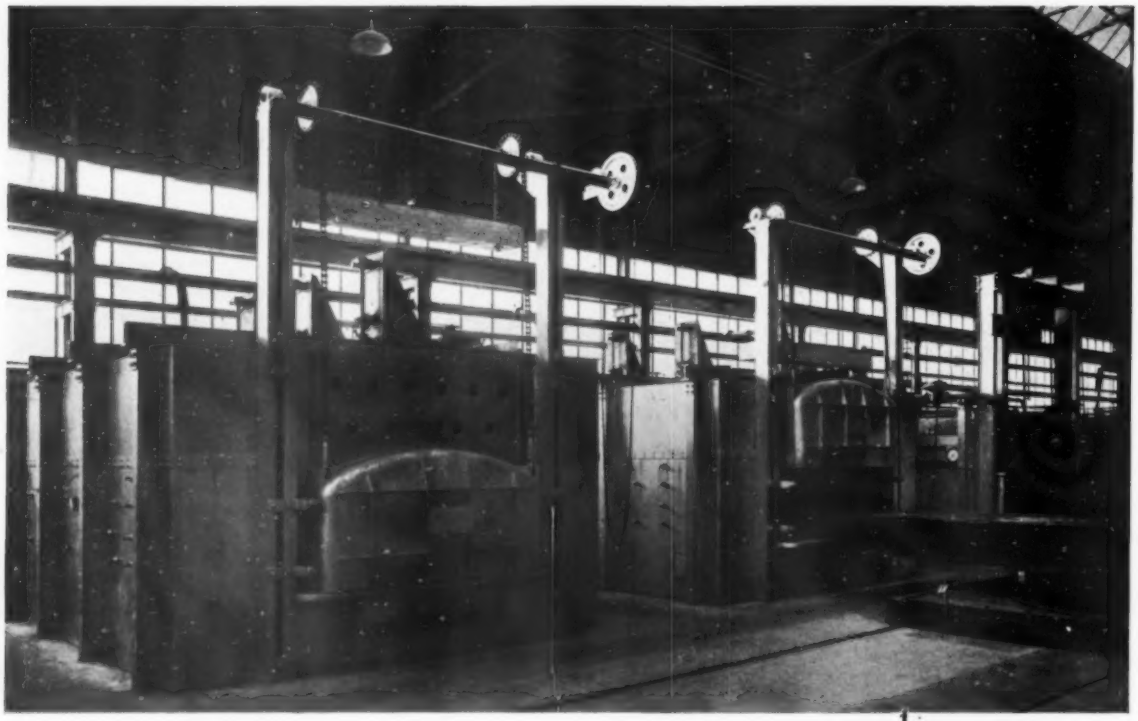

The above illustration shows a battery of Gas Fired Muffle Furnaces for Annealing Light Alloy Sheets.

Reliable results sought in heat-treating practice depend upon the proper combination of the man, the furnace, and the material. Good material is entitled to proper treatment in good furnaces, and both should have the services of good men.

No two cases are alike, and no type of furnace has a monoply on uniformity of heating or economy in operation; for this reason we, as specialists, design heat-treatment furnaces to suit your particular conditions and products; in this way reliable results can be assured, with the utmost economy.

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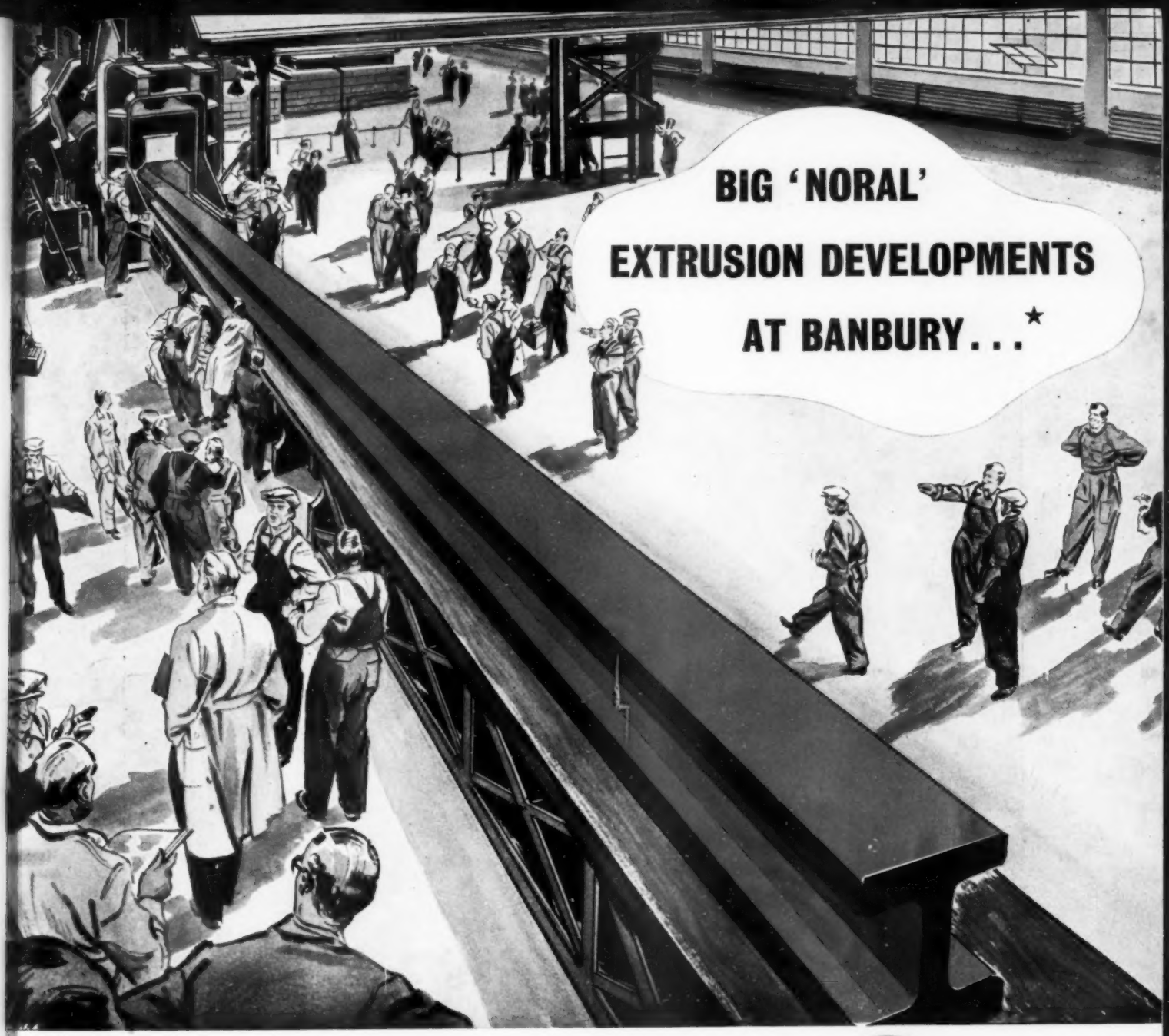

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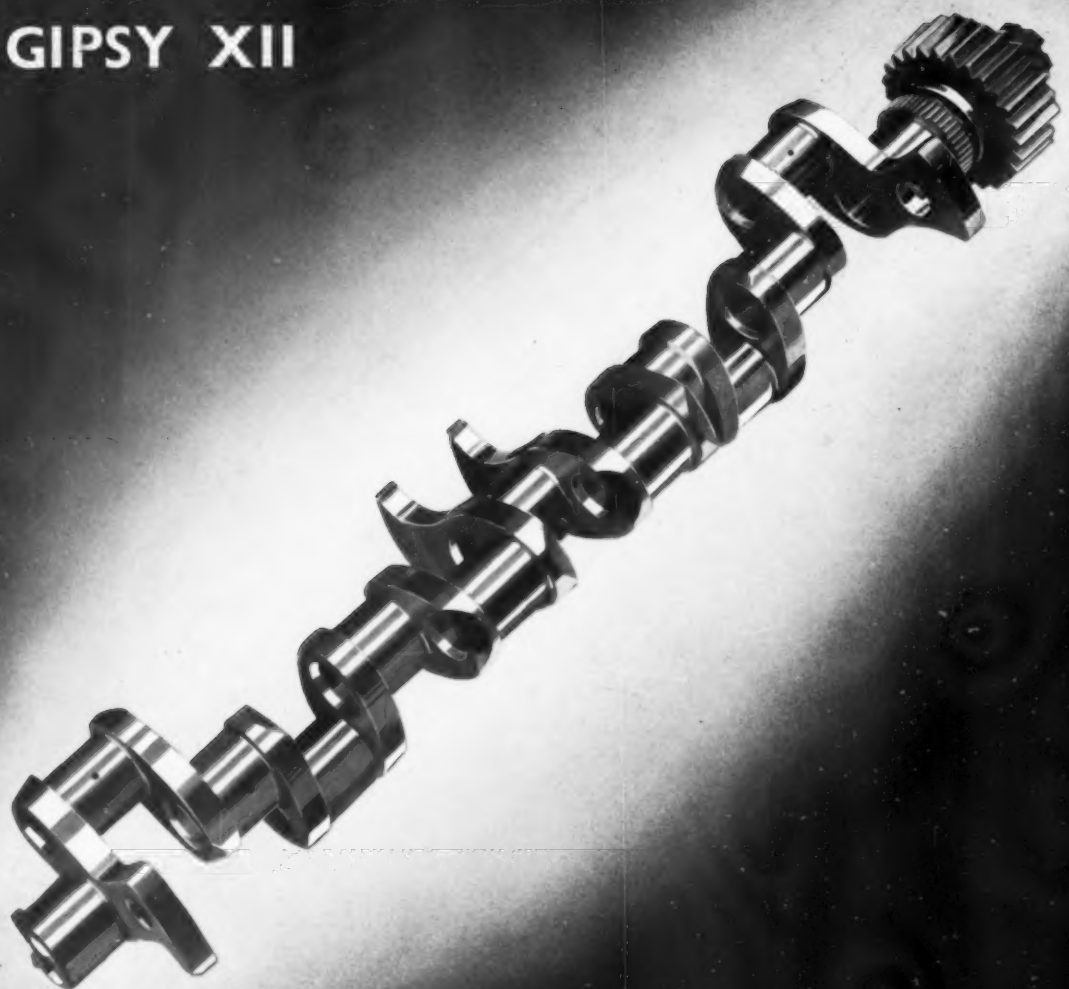

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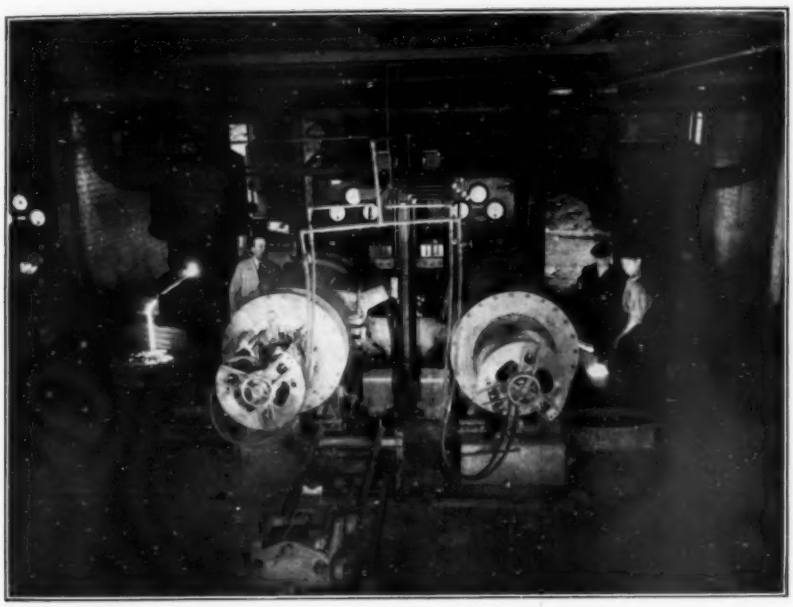

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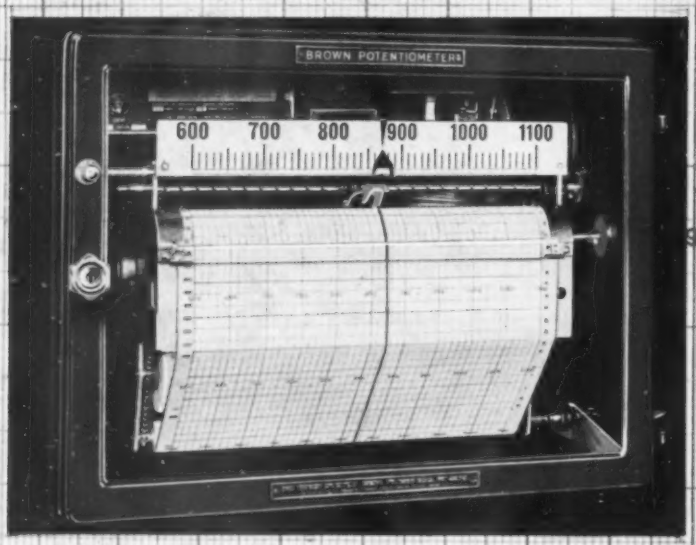
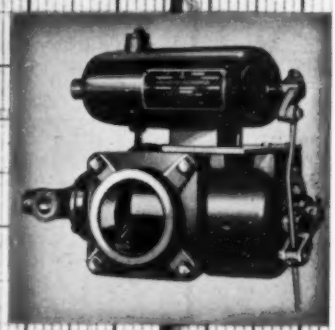


. . . . the Honeywell-Brown Potentiometer Pyrometer and (right) the H.-B. Motorised Valve. H.-B. Pyrometers are available to control, record and indicate temperatures from 0°-3,000° and all have charts 12" wide. At "Ebbw Vale" many H.-B. controls and instruments are installed.



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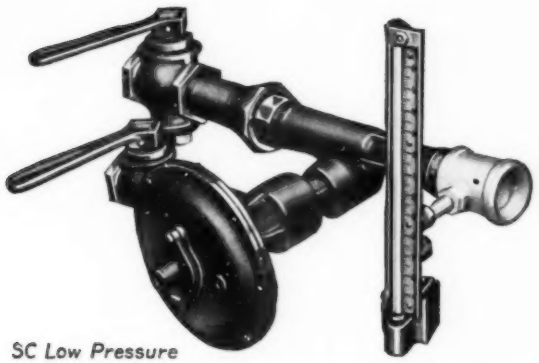

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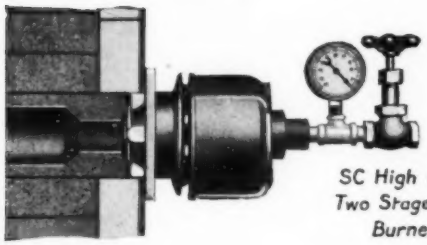
SC High Pressure Inspirator Set



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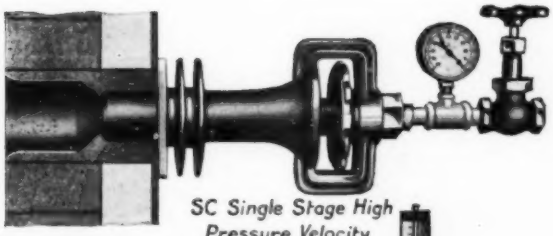

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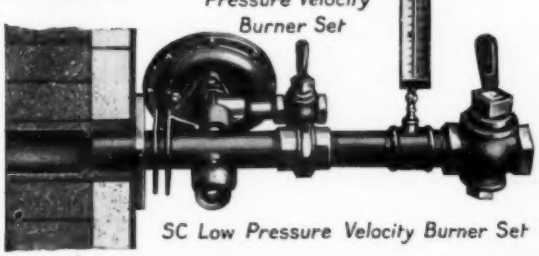

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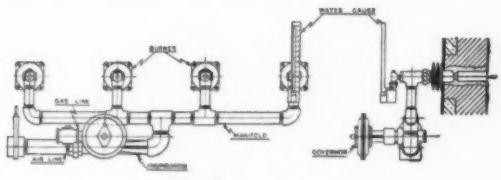
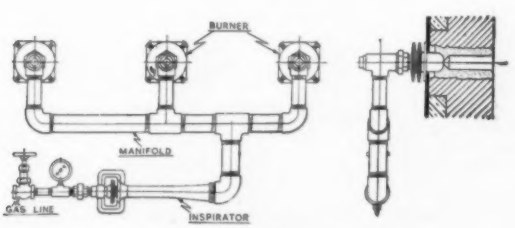


Low Pressure System



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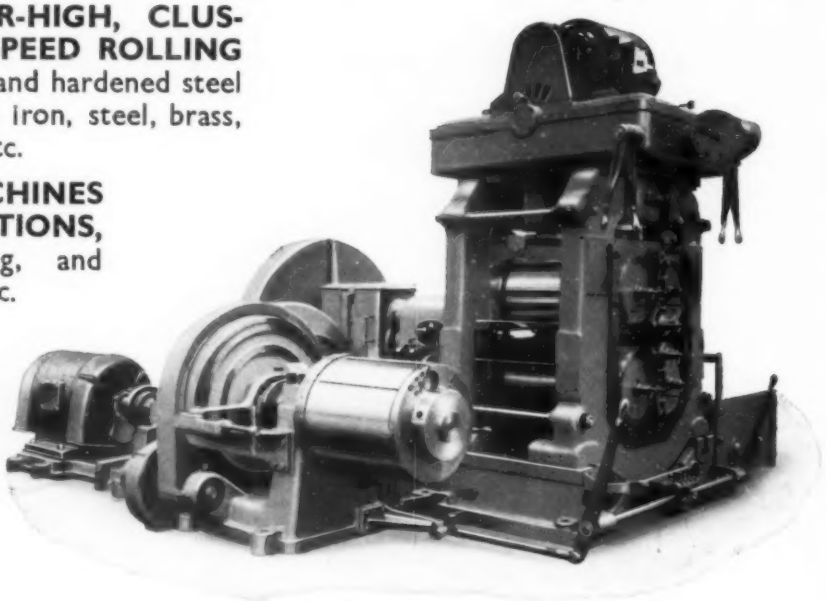

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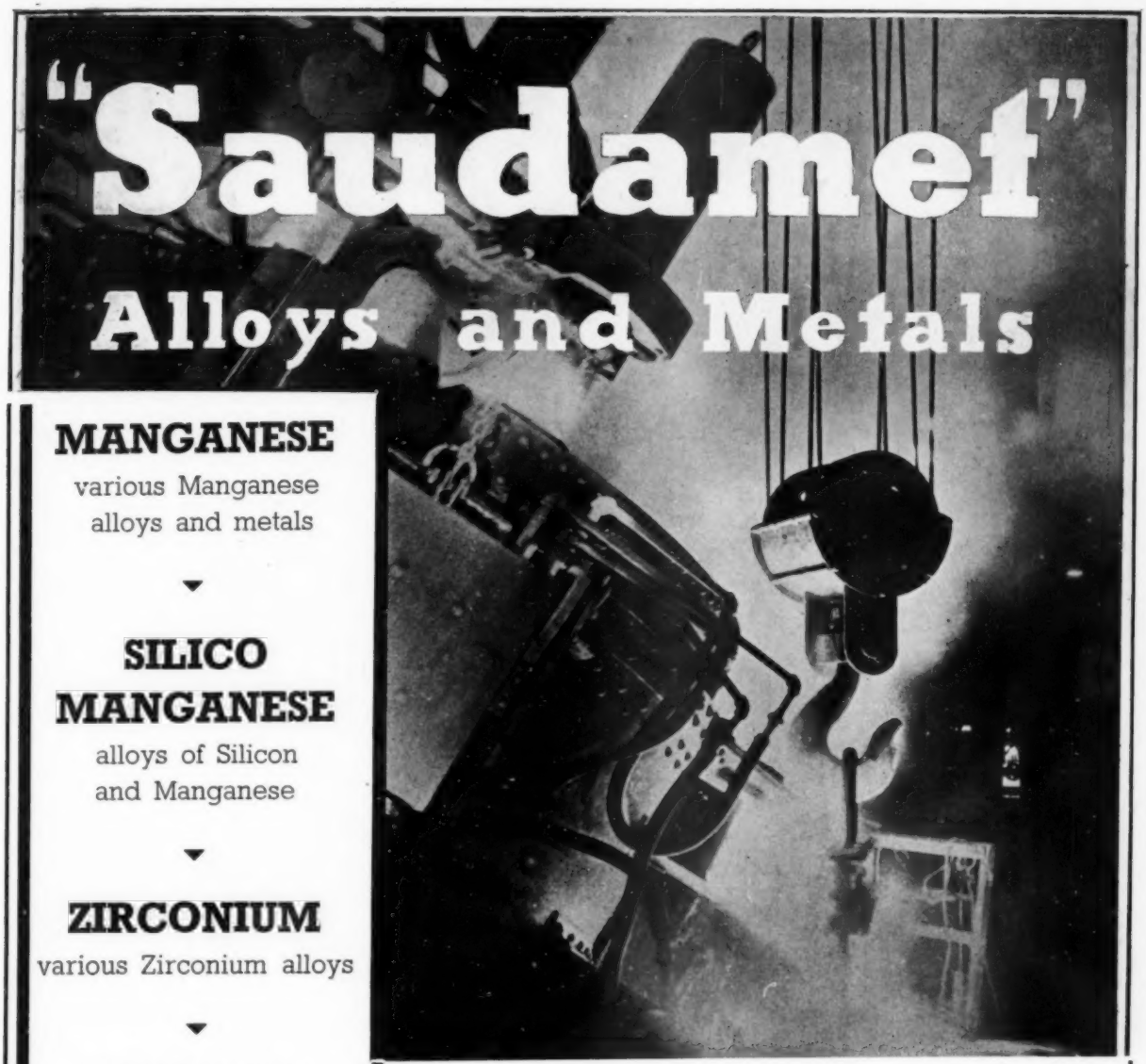

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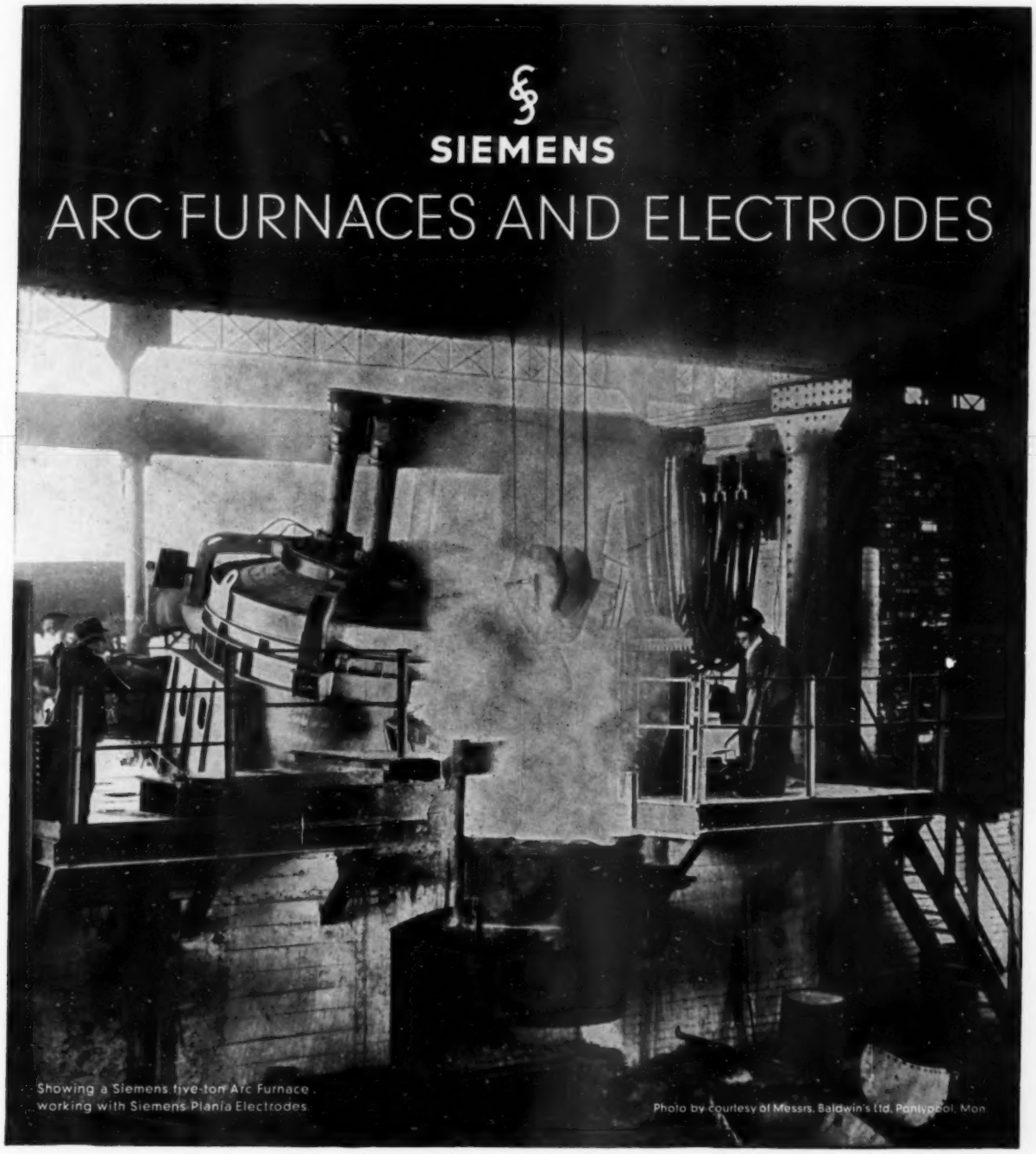
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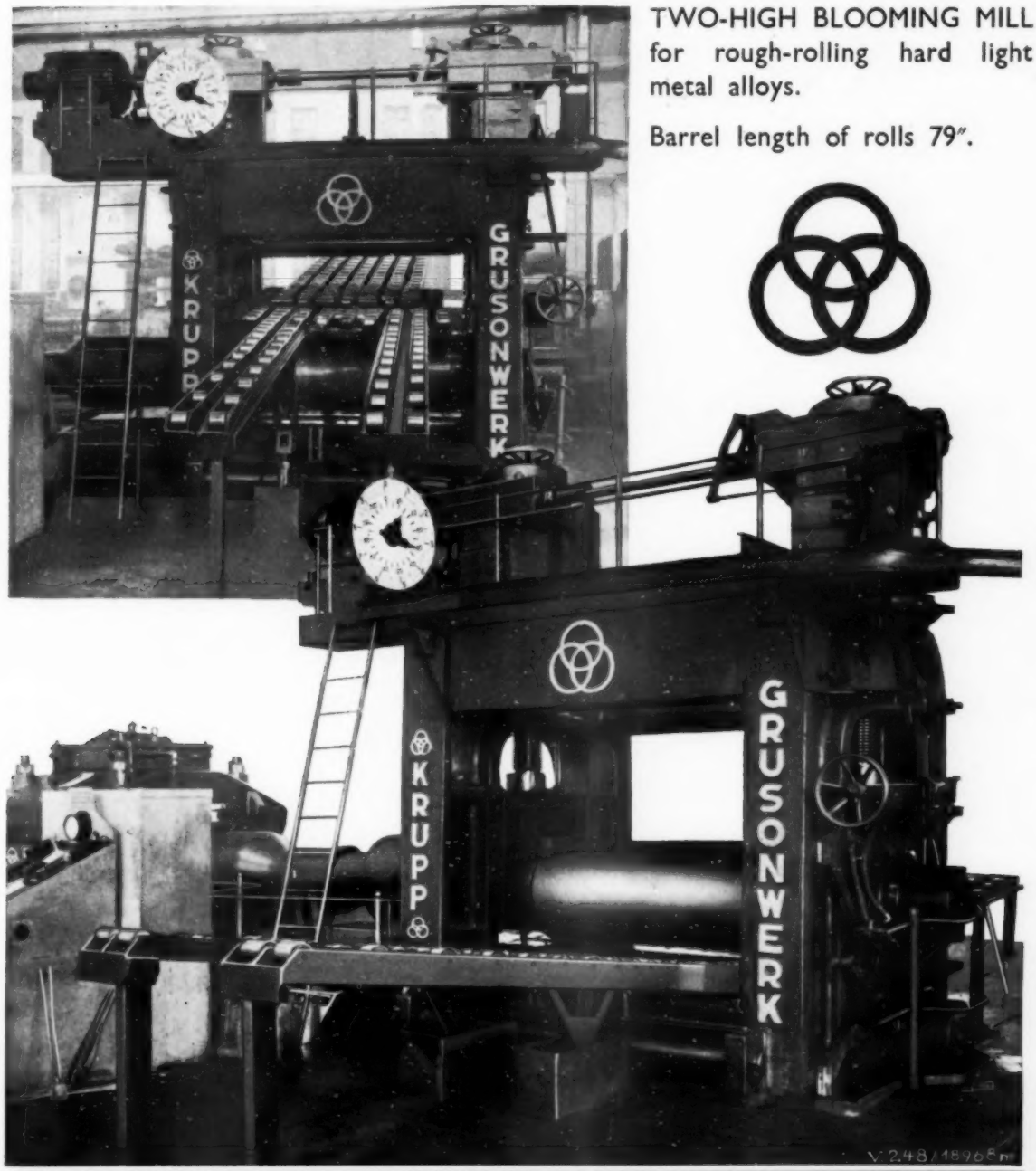

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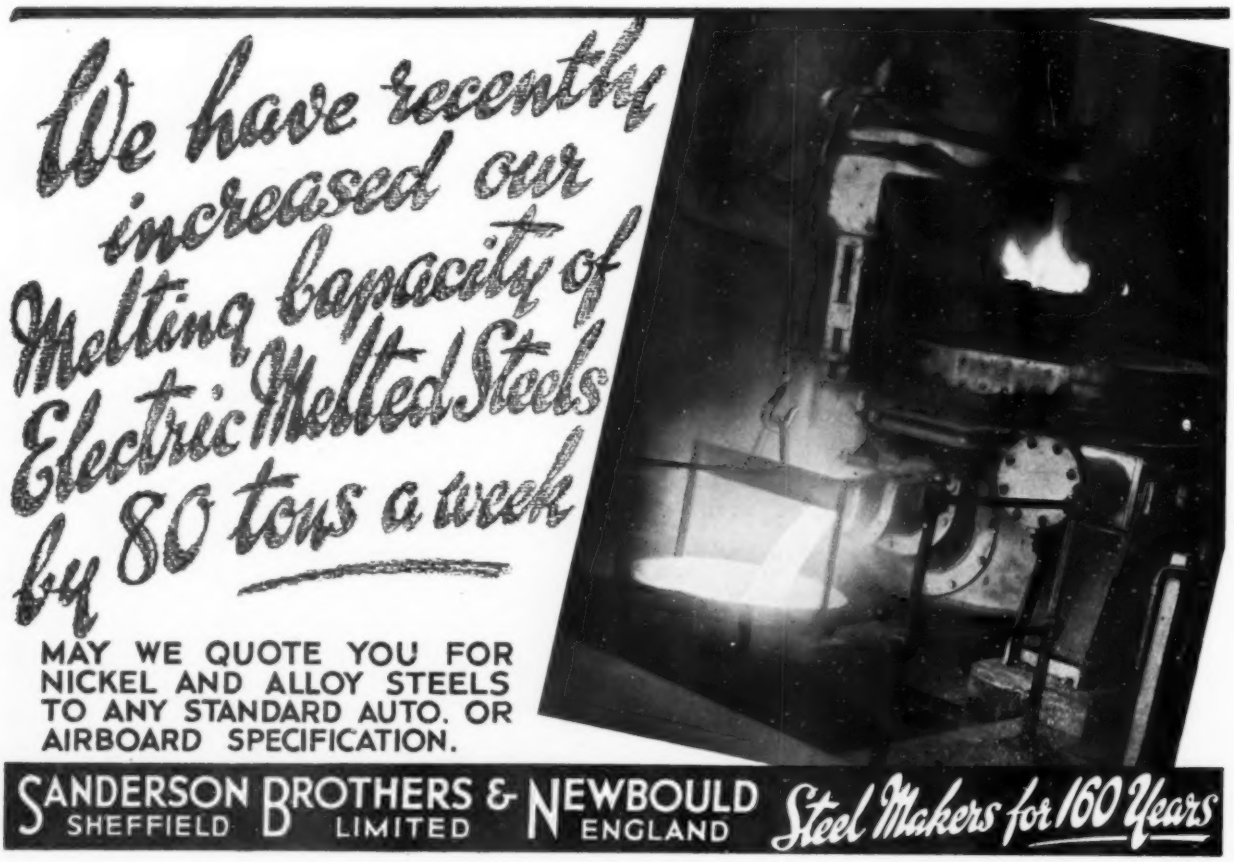
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Progress in the Iron and Steel Industry

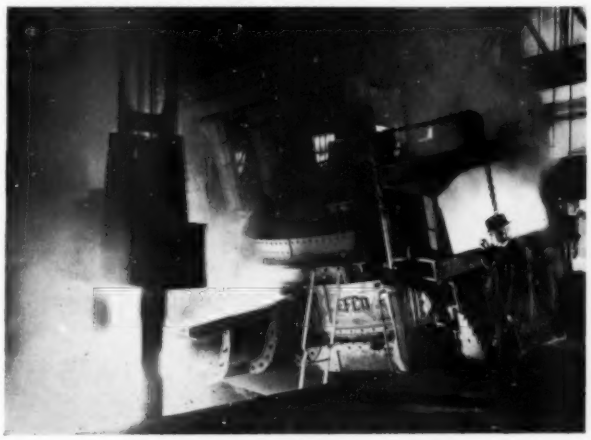
Although the iron and steel industry has been faced with difficulties as a result of falling trade during 1938, unceasing efforts have been made to maintain various British plants in a high state of efficiency and to facilitate production of increased tonnages with improving conditions. Some developments are briefly discussed.

THE British iron and steel industry experienced a considerable falling off in trade during 1938, as compared with 1937. During the greater part of the year the attitude of consumers was very cautious, but towards the end of the year there were definite indications of improvement in iron and steel markets, which developed, and an expansion of business in practically all departments was experienced. To-day the recession in the steel trade certainly seems to have been definitely checked, and more steel furnaces are now working. There is not yet any marked broadening of commercial demand, but a number of firms have received a good deal of work in connection with rearmament, and structural steel is fairly active. Very little has occurred to improve appreciably the outlook of the plate mills, which are securing very little new business from the shipyards; but stocks of sheets have been greatly reduced, and these are gradually being made good. It seems to indicate that while the requirements of the accelerated armaments programme is a cause of improvement in demand, there has also been a revival in demand for ordinary commercial purposes, but it is noteworthy that increased activity is almost entirely confined to the home market.

In the pig-iron section there has been increased demand. Most consumers of foundry iron have exhausted their stocks and are turning to makers for deliveries which are being made from dwindling accumulations at the works. Makers of hæmatite are delivering larger tonnages against old contracts, and progress is being made in the liquidation of stocks which remain. The position has eased considerably, and there is increased call for specifications. Considerable tonnages are also reaching the steelworks. It is noteworthy that the fall in imports of both iron and steel is very marked.

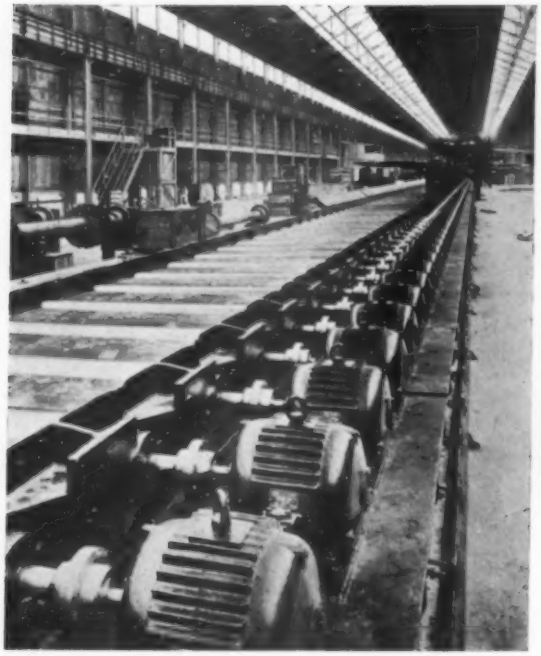
Despite the recession experienced during the year, the iron and steel industry has continued its developments to increase production facilities, and some noteworthy installations have either been put into operation or are approaching that stage. One of the most important developments in recent years is the continuous-mill equipment for steel sheet and strip; the method has proved less costly than older methods when the increased output can readily be absorbed. Undoubtedly, the most important installation of this kind is that put into operation at the Ebbw Vale Works of Richard Thomas and Co., Ltd. These mills embody all the latest improvements in order to produce sheet at the minimum cost. To maintain the plant on production considerable attention has been given to auxiliary equipment. Of outstanding interest are the centralised pressure oil systems, centralised pressure grease system, a hydraulic descaling system, palm oil distribution, roll contour control, and roll cooling system—the complete work for these auxiliaries having been carried out by the Inter-Continental Engineering Co., Ltd., of London.

A total of 6,400 in. of meshing gear face in the main drives of the 44-in. blooming mill, the 56-in. hot-strip mill, the hot-finishing department, the five-stand tandem cold tin mill; the three-stand tandem cold strip mill, and the cold-finishing mills, together with 450 bearings, demand adequate lubrication. All receive a supply of lubricating oil of the correct consistency and in correct quantity automatically, through a constant circulation system involving four miles of pipe-line, and a total volume of 38,000 gals. of lubricant, which is distributed from seven points. Oil is maintained in a central reservoir at constant temperature, and is filtered down to a fineness of 0·006 in.

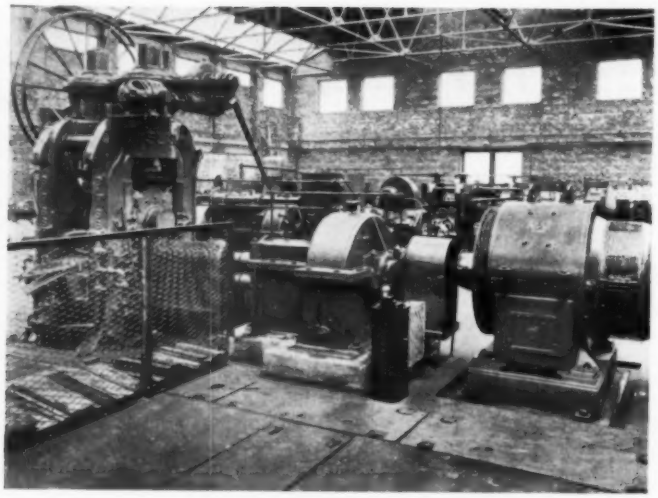


A battery of electric arc and high-frequency induction furnaces at the Vickers Works of English Steel Corporation, which includes the above electric arc furnace claimed to be the largest in Europe.

7,000 h.p., 21,000 h.p. peak 0/50/120 r.p.m., 800 volts D.C. reversing mill motor by Metropolitan Vickers Electrical Co. Ltd., driving the blooming mill at Ebbw Vale Works of Richard Thomas and Co. Ltd.



Run-out table utilising 241 B.T.-H. motors in the new Ebbw Vale Steel Works of Messrs. Richard Thomas and Co. Ltd.



Rear view of rolling mills at Works of Messrs. Darwin Ltd., showing B.T.-H. electric drives.

by automatic self-cleaning filters before being pumped under constant pressure to the various points of application, where sight-feed valves meter the quantity delivered to bearings, and special spray nozzles apply the oil under pressure to the gear faces.

After use, all the oil is returned to the used-oil compartment of the main reservoir. Continuous oil purification and dehydration is by centrifugal equipment, this removing any free water, solids, such as dirt, metal particles, or pipe scale, as well as any sludges of different specific gravity and which are insoluble in the oil itself.

There are some 16,500 additional bearings in the rolling mills and auxiliary equipment, designed for grease lubrication. Two types of grease-distributing equipment are used, both completely automatic. In one type of system, grease is maintained in a central reservoir, from which point it is pumped through high-pressure distributing headers. Sub-headers, branching off where required, have banks of distributing valves actuated by electrical tripping units; time-clock control actuates these tripper units at any predetermined time interval, each unit operating the bank of grease distributors to which it is connected. The valves are separately adjustable.

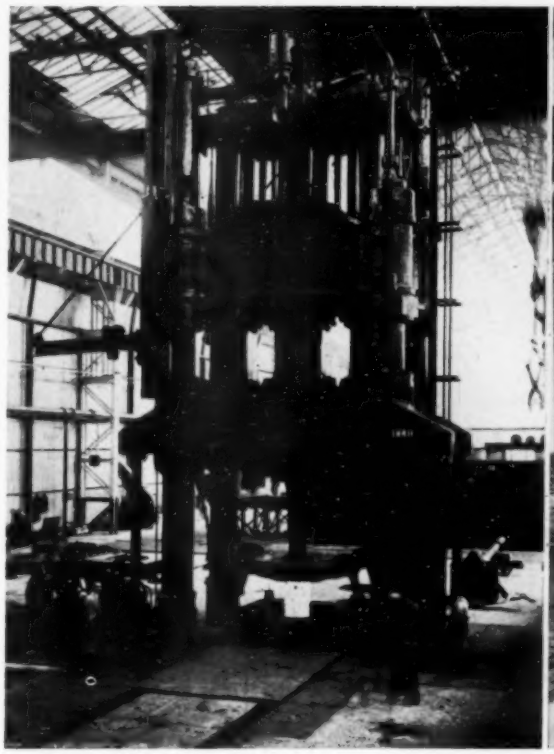
In the other system the operation of the grease pump is controlled by a time clock on the main control panel; the time clock operating the pumping mechanism at predetermined intervals, dependent upon the application, and delivering grease from the pump to the main distributing headers. These are fitted with pressure control at their extremities. Thirty miles of pipe are entailed, with delivery from seven main and 100 auxiliary points. When all distributing valves have been actuated and the grease pressure has built up to a predetermined figure at the main header point farthest from the pump, the pressure control operates and shuts down the pumping unit, which is then ready for the next cycle, as instituted by the time clock.

Descaling of the steel rolled in the 56-in. mill is done by an automatic hydraulic system, this consisting of two special split casing centrifugal pumps, each delivering 800 gals. of water per min. at approximately 1,200 lb. per sq. in. pressure into a hydraulic header running the length of this hot-strip mill. Riding upon this header is a hydro-pneumatic accumulator for supplying peak-load water demands and controls, through the medium of pressure control switches, the operation of automatic valves in the discharge lines of the centrifugal pumps and the accumulator.

As the strip approaches any of the six descaling stations, a flag in the mill table is depressed, causing a rotary limit switch to make contact, this then actuating the solenoid of a four-way automatic air valve which operates a hydraulic valve controlling the spray. The high-pressure water is discharged upon the upper and lower surfaces of the strip through nozzles with definite discharge characteristics.

Both tandem cold mills are supplied with palm oil from two underground tanks of 10,000 gals. each; the oil drawn from these tanks is raised in temperature and passed through centrifugal dehydration equipment before being pumped under constant pressure to the various points of application, each of which has an automatic solenoid valve

Battery of gas-fired furnaces at English Steel Corporation's works which ensure uniform treatment of drop forgings.



(Left) The vertical hydraulic billet piercing press in operation at the Chesterfield Tube Co. Ltd.

(Right) The bogie tunnel furnace, by Priest Furnaces Ltd., showing preheated material prior to being transferred to the soaking pit.

permitting palm oil to be sprayed to the tinplate stock being rolled.

The external and internal roll-cooling system comprises an automatic recirculating water system employing high jet velocities applied to the external roll surfaces. Water also enters the centre of the work roll, is conducted to the other end through an internal tube, and returns through the annular space between the interior of that roll and the exterior of the tube, finally being collected by a rotating fitting.

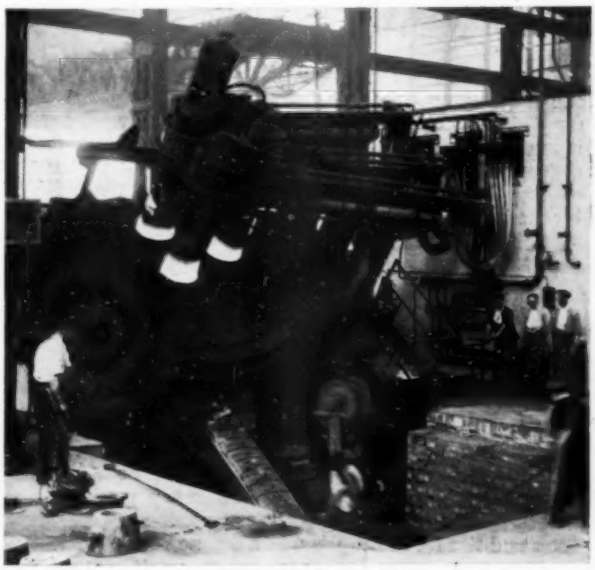
This new strip mill of Richard Thomas and Co., Ltd., is designed by Davy and United Engineering Co., Ltd., and the electrical plant for the various mills and auxiliaries was supplied by Metropolitan Vickers Electrical Co., Ltd., General Electric Co., Ltd., and British Thomson-Houston Co., Ltd. The majority of the mechanical plant for the cold-rolling section of the scheme, including three skin-pass mills, the shearing line, a number of coilers, de-coilers, shears, a tensioning device, and other auxiliary equipment in connection with the manufacture of cold sheet and tinplate, is the work of Fraser and Chambers Engineering Works of the General Eelctric Co., Ltd.

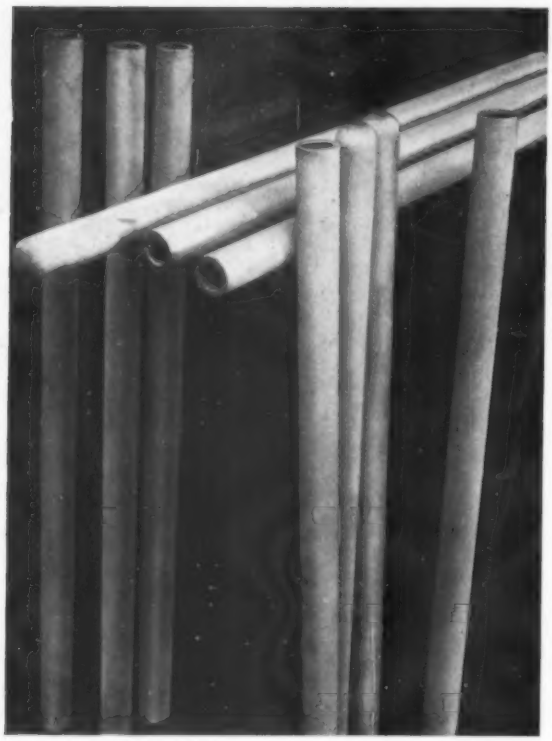
An interesting equipment for cold-rolling strip is being manufactured for the Whitehead Iron and Steel Co., Ltd., of Newport, Monmouthshire, which comprises a four-stand tandem and two single-stand mills; the tandem mill can be operated either as a three- or four-stand mill, being equipped with two motor-driven coilers, one between the third and fourth stand for use when operating as a three-stand mill, and the other following No. 4 stand for use when operating as a four-stand mill. Each of the single-stand mills is also equipped with a separate motor-driven reel, and the equipment is specially designed to maintain constant tension in the strip between the mill and the reel over a wide range of speed and tension requirement. The mills will be electrically driven, the electrical equipment being manufactured by Metropolitan Vickers Electrical Co., Ltd.

Continuing the programme of reconstruction and modernisation of the whole of the plant at their Vickers Works, English Steel Corporation have completed the reorganisation of their drop-forging department, which is now one of the largest and most modern in the country. To give some idea of its capacity it is only necessary to mention that during stocktaking there were half a million drop forgings of all types in process of manufacture or ready for despatch. The plant includes 65 stamps and hammers ranging from 15 tons to 5 cwt., which produce drop forgings for automobiles, commercial vehicles, aircraft and general engineering work, varying from 600 lb. to 1 lb. in weight, and it is interesting to note that what is claimed as the world's largest drop forging was forged in this department.

The important heat-treatment of forgings is efficiently carried out by two batteries of gas-fired furnaces, 17 arranged in one bay and served by two ground-type chargers, and eight in another bay. Uniform treatment

Tapping one of 10-ton electric furnaces at Hadfields Ltd.



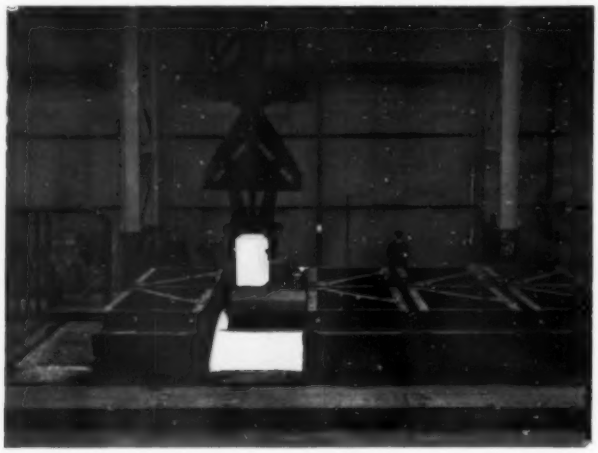


High-temperature resisting sheaths by Darwins Ltd.

is assured by the fitting of temperature control and recording instruments, whilst the latest type of oil- and water-quenching tanks are also laid down. In the extensive die-sinking department the alliance of skilful craftsmen with modern plant ensures the production of dies to give forgings of maximum strength and efficiency.

The works, which cover about 170 acres, now include acid open-hearth furnaces representing the latest word in scientific melting practice, and capable of casting ingots up to 260 tons in weight; a battery of electric arc and high-frequency induction furnaces, which includes the largest electric arc furnace in Europe, is responsible for the high-grade carbon and alloy steels; forges capable of producing all types of forgings up to 160 tons in weight, and heat-treating and machining them to the high degree of accuracy and finish required for this class of work; machine shops with nearly two miles of bays for dealing with the products of the various departments which range from a few pounds up to 250 tons in weight; a heat-treatment department with a range of furnaces suitable for dealing with forgings varying from a few hundredweights to upwards of 150 tons in weight, and anything up to 80 ft. in length; steel foundry laid out to produce steel castings from a few pounds up to 150 tons in individual weight, for general engineering and mill work, railways, electric equipment, water and steam turbines, chemical industry, shipbuilding, dredging, and mining; rolling mills for blooms, billets and bars for automobiles, aircraft and general engineering work, including a new 10-in. double-duo mill for accurate rolling of high-class steels; a new department for the production of precision ground bars (round and hexagon), and a spring department for the production of laminated, helical, and volute springs in carbon and alloy steels, and for railway rolling stock and motor vehicles.

With the increasing use of blast-furnace gas for metallurgical purposes, and improved technique in the control and burning of this clean gas, the Park Gate Iron and Steel Co., Ltd., considered it necessary to clean all gas produced, thereby increasing the efficiency of the consuming units and bringing into useful service a greater volume. After reviewing the several processes for cleaning blast-furnace



The soaking pit, also by Priest Furnaces Ltd., showing pre-heated material ready for transport to the piercing press.

gas, it was decided to adopt the electrostatic precipitation type. The contract was placed in the hands of Messrs. Lodge-Cottrell, Ltd., and the plant consists of two pre-treater units and two final treater units, the total average capacity being 4,000,000 cub. ft. of gas per hour at normal temperature and pressure.

Clean blast-furnace gas being available, the Cowper stoves have been chequered with "Hotspur" fillings supplied by Henry Foster and Co., Ltd. Specially designed gas burners and chimney valves are also installed with a Foster hot-blast temperature regulator. As a stand-by, and in cases of a complete shut down of the blast-furnaces, a steam turbo blower has been installed with a capacity of 30,000 cub. ft. per min. at 10 lb. per sq. in.

The chief activities in the steel shop have been directed towards increasing output by improvements in the design of the furnaces, and the use of higher quality refractories. To deal with the light scrap, and reduce charging times, a "scrap-bundling plant" has been built, which has a pressing capacity of 10 to 12 tons per hour, the bundles weighing 8 cwt. to 10 cwt. each.

The 12-in. mill building has been extended to give increased billet storage and extra loading facilities. A new and completely redesigned five-stand train of rolls and housings has replaced the old type of equipment in the 10-in. mill. The new features are totally enclosed bearings in the finishing and oval stands, and semi-enclosed bearings in the three other stands. Another development at these works is the increased laboratory accommodation necessitated by stricter and more accurate control of both incoming materials and the finished steel.

During the year Hadfields, Ltd., have increased their steelmaking capacity by the installation of two 10-ton and one 5-ton electric arc furnaces, which are used for the manufacture of high-grade alloy steels, particularly associated with castings and forgings used in the construction of aircraft. The efficiency of the foundry has been increased by the installation of a number of new moulding machines, sand conveyers, and core-making plant, and the steel-making capacity augmented by the installation of a 650-kw. high-frequency electric-furnace plant, with three separate melting units of 2, 1, and ½ tons capacity. For the heat-treatment of carbon and manganese steel castings, two continuous annealing furnaces have been installed. The machine shops have also been improved, and a large number of highly efficient machine tools installed, whilst the electric supply for a proportion of the works has been changed from D.C. to A.C.

Edgar Allen and Co., Ltd., report that the most important development has been the increase in the production of, and demand for, the firm's Allenite tungsten-carbide-tipped tools and tips for cutting cast iron and non-ferrous materials

generally, chilled iron rolls, and, in certain special circumstances, for cutting steel. The production of their butt-welded high-speed steel-cutting tools has been intensified to such an extent that the production plant has had to be continually extended. The track-work department, which has been exceptionally busy, and the steel foundry has been steadily employed in the manufacture of steel castings for general purposes, and of alloy steel castings to meet specific requirements. The plant of this section of the firm has been steadily improved, and in 1938 a large sand-drying and reclaiming equipment was installed with beneficial results.

A notable departure in the Scottish steel industry is the hot-metal process about to be operated at Colville's Clydebridge Steelworks, in the new integrated steel and iron plant. Although the hot-metal process was originally pioneered in the Wishaw Steelworks and was used for about a year in the Glengarnock Steelworks shortly after the war, the blast-furnaces and steel plants of both these works are now dismantled. Apart from these, the Scottish steel industry has always been dependent on cold pig iron and scrap, due to the scattered location of the works, but this new development will make an important change when completed and in operation.

Interesting developments are in progress at Messrs. Darwins, Ltd. A two-stand, four-high tandem cold-strip mill, and two two-high skin-pass mills are under construction for rolling stainless steel strip of high quality. The B.T.-H. Co. are supplying the electrical equipment. Messrs. Darwins have given considerable attention to the development of alloys for use at high temperatures. They have introduced a number of alloys, each of which has been carefully developed to meet specific needs. These alloys are marketed under the brand name of " Pireks," and the material is produced by the high-frequency electric steel-melting process. The complete range of alloys for use at high temperatures comprise nine different alloys. In addition to standard materials, five new alloys have recently been introduced and represent newer developments of heat-resisting materials.

Another steelworks where extensive developments are in progress is that owned by John Summers and Co., Ltd. Faced with the position created by the modern hot- and cold-strip mill at Ebbw Vale, this firm has proceeded with the installation of a continuous strip mill of a similar type. The new mill, which is being erected to the design of the Mesta Machine Co., of Pittsburg, is expected to be completed by the end of the present year.

Mention may also be made of the works extensions of the Chesterfield Tube Co., Ltd., which have recently been put into operation. The plant installed consists of a vertical hydraulic triple-cylinder billet-piercing press of a power sufficient to pierce ingots up to 20 tons in weight. The press is capable of producing in one operation a hollow forging 9 ft. long. A horizontal hydraulic tube draw bench, included in the equipment, is also of triple-cylinder type, the maximum stroke being 40 ft., and hollow blooms of approximately 20 tons can be mandrel drawn. The furnace equipment comprises a bogie tunnel furnace of the multi-pass regenerative type, a soaking-pit furnace of the multi-pass regenerative type, and a recuperative tube-reheating furnace. The furnaces were built by Priest Furnaces, Ltd., and are gas-fired from the coke-oven gas grid supplied by local collieries.

A new stage in Jarrow's development was put into operation during the year by the opening of two works: the Jarrow Tube Works, which is sponsored by Messrs. Stewarts and Lloyds, Ltd. and Tubes, Ltd., and Jarrow Metal Industries. The former is designed and equipped for the manufacture of hot finish, cold-drawn seamless to fine limits, and bright-annealed tubes in sizes ranging from 3 in. down to smaller diameters.

It has only been possible to refer to very few of the developments completed or in progress during the year, but sufficient has been given to indicate that the British iron and steel industry is alive to the need for the installation and maintenance of plant of a high standard to meet demands for high-quality materials at competitive prices.

Steels for Valves at Low Temperatures

ALTHOUGH some of the physical characteristics of metals change favourably with decrease in temperature—this applying to tensile strength, yield point, modulus of elasticity, and hardness—shock resistance is adversely affected; and, as metals for valves may be required for service in temperatures below zero, the quality of resistance to shock assumes major importance. Valves may have to withstand internal pressures, sudden shocks from water hammer, pump vibration and accidental mechanical impact. This question becomes of increasing importance in the field of chemical processing where temperatures of $-50°$ to $-75°$ F., and pressures up to 300 lb. sq. in. may be required.

It is generally agreed that the factors which control the shock resistance are those of chemical composition of the metal; the heat treatment applied; the grain size, particularly after heat treatment; whether the metal is cast or forged; and the foundry technique employed in producing metal.* To provide satisfactory shock resistance many specifications call for a minimum Charpy test of 15 ft. lb. of absorbed energy, made on a standard 10 × 10 × 56 mm. specimen with keyhole notch, and at the minimum temperature at which the metal is to be stressed. Tensile properties are tested at room temperature.

The high nickel-copper alloys and the austenitic chrome-nickel-iron alloys, have long been known to possess high impact resistance at subzero temperatures together with satisfactory tensile strength and corrosion resisting properties for most applications. But both are comparatively costly and demand special foundry technique in casting.

It has been found that a suitable metal for valve castings is an alloy steel containing 2·5 to 3% nickel, which can be produced at relatively low cost when cast and properly heat treated. A typical steel of this classification could have:—Carbon 0·25%; manganese 0·60%; silicon 0·25%; phosphorus 0·046%; sulphur 0·045%, and nickel 2·92%. A material stated as being satisfactory for studs or bolts or forged parts has carbon 0·40%; manganese 0·69%; silicon 0·21%; phosphorus 0·016%; sulphur 0·018%, and in place of nickel we have chromium 0·99% and molybdenum 0·23%. Both these alloys are amenable to fabrication, forming and machining; and demand suitable local heat treatment after welding.

If surface hardening is needed, carburizing can be employed, and tests have shown that spalling off of the hardened surfaces at temperatures below zero would be unlikely unless the thickness of the hardened case were excessive. This surface hardening may be necessary to reduce the possibility of galling where the parts of the valve are in sliding contact with other parts of the same metal and under high pressure.

The valve metals which may be required for this subzero service would include both cast and forged, or rolled materials, for fabrication as bodies, covers, bolting material, stems, meters, pipe fittings and so on. It appears likely that extended use of processes with extremely low temperatures and high pressures will be seen, so this question of suitability of metals becomes of considerable interest and importance.

Ind. and Eng. Chem. 1220-20. 11. 38.

Nature of Oxide Inclusions in Foundry Cast iron

AN investigation by F. W. Scott on the extraction of oxide inclusions in high-carbon iron was reviewed recently.* This investigation was carried out to determine whether wide variations in four of the principal metalloids—manganese, silicon, sulphur, and phosphorus—affected the amount or composition of the oxides in cast iron, and the results obtained indicated that the electrolytic method of extraction provided a satisfactory means of studying oxide inclusions in cast iron. As little data are available concerning the nature and analyses of such oxides in foundry iron, and as a suitable method of extraction had been developed, further work was carried out by F. W. Scott and T. L. Joseph[1] on this subject.

Samples of plain cast irons representing several types of melting practice were obtained at different times from foundries. The oxides were extracted from large solid pieces by the electrolytic iodine method, using two methods of sampling in view of the possibility of a rambling distribution of inclusions and of possible accidental inclusions. In the first method, two discs $\frac{3}{16}$ in. thick were cut from the centre of dry sand test-bars 18 in. long by 1·2 in. diameter, and in the second three rectangular blocks, 2 in. × $\frac{3}{4}$ in. × $\frac{3}{16}$ in., were cut from a rectangular chill bar cast in a split graphite mould made from a graphite electrode, one block being cut from the top of the bar, one from the bottom, and one from the middle. Each of the blocks was extracted separately, and the average results used for the amount and analyses of the oxide.

From the chemical analyses and oxide analyses of the irons, it was apparent that a small amount of sand had been washed into the sand-cast samples, as all such samples contained higher percentages of S_1O_2 than any of those cast in the graphite mould. As special precautions were taken to grind the surface of the test samples before their extraction, the results obtained represented the metal itself and not any sand in the skin of the casting. The irons cast in the graphite mould were remarkably constant in silica content which ranged from 0·0038 to 0·0063%, values which compare favourably with the cleanest steels dioxidised with silicon.

The MnO was present in very small amounts, the range being from 0·0001 to 0·0007%, but due to the presence of over 3·0% carbon and over 2·0% silicon little MnO was expected. The FeO with one exception was very low, the average of 12 tests being 0·0050%. This FeO may be present in two forms, either in pure form as dissolved FeO, or combined with silica to form a high melting point ferrous silicate. As the FeO percentage is controlled by the silicon-ferrous oxide equilibrium, and as the quantity of FeO was close to the equilibrium value, most of the FeO was present as such in solution, and very little present as silicate. This conclusion was substantiated by observations made with the binocular microscope on the oxide residues.

Tests made from the top, bottom, and middle sections of the chill cast bars showed the oxide to be evenly distributed, and indicated that the sampling and method of determination was reliable. The only other data with which those results could be compared were those obtained by the vacuum fusion or hydrogen reduction methods. Comparing the calculated oxides of the compounds determined, it was found that they agreed within a limit of + 0·002%, which was the accepted value for the permissible variation in tests made by those other methods.

A number of samples of the cast irons were examined under the microscope in order to study the type of inclusion present, its distribution, and its association with the graphite. All samples were cut under similar conditions, and the section examined was cut from a similar location in each bar and the examinations made at 100, 500, and 1,000 diameters. The graphite, in all cases, was present in long flakes, although there was at times a slight difference in the thickness and length. There was no evidence to support the theory that graphitisation was dependent upon the presence of non-metallic nuclei, although some inclusions appeared to be associated with the graphite. No nodular graphite was seen, and no irregularities were observed. The presence of many crystalline shapes suggested that there were present different oxides, such as Al_2O_3, T_1O_2, and S_1O_2, although it was also thought that some of the particles were sulphides, such as manganese sulphide. It is suggested that the future study of oxide residues under the polarising microscope might afford more definite information as to their identities.

*METALLURGIA. October, 1938.

1 *Metals and Alloys.* 1938. Vol. 9, No. 11, pp. 299-302.

Alternating Strength and Crystal Structure

THE purpose of a recent investigation by Hermann Möller and Max Hempel* was to find out, by means of X-ray photographs how far changes of the crystal structure could be proved as being caused by alternating strength tests, and whether a physical explanation could be given.

The material tested was carbon steel of 0·02% C, a trace of Si, 0·37% Mn, 0·052% P, and 0·025% S; it was subjected to a special annealing method in order to obtain suitable crystal sizes and clear photographs. Fatigue tests were made on completely etched test-pieces, and on pieces with an artificial defect, and further tests under static load.

The following results have been obtained:—

1. When the applied load exceeded the alternating stress deformations of the lattice structure soon took place in numerous crystals; more and more crystals were affected as the test was prolonged, and the degree of the deformations increased, but they generally remained small until just before the fracture.

2. When the applied load remained below the alternating stress no changes of the crystal structure could be observed. Only immediately under the alternating stress were small deformations of individual crystallites and the degree of the deformations were less than at loads above the alternating stress.

3. At static loads up to the upper yield-point no greater lattice deformations took place than at loads below the alternating stress.

From these observations some conclusions can be drawn: It is possible in principle to predict a fatigue fracture by means of an X-ray photograph, if certain conditions are fulfilled in applying this method of investigation. The use of the method in practice, however, is still doubtful. It has to be considered that the observations are made on a material having a specially prepared structure, and it will not be applicable to bridges, machinery, aeroplanes, etc. Heat-treated steels especially must be excluded completely, because the reflexes of single points, necessary by the X-ray method, cannot be obtained in these cases. Whether it may be possible to overcome this difficulty by change of the conditions when taking the photographs cannot be decided at present.

Thus, the results are important in so far as the process of alternating strength can be explained physically; the alternating strength leads, as soon as the alternating stress is exceeded, to deformations of the crystallites of a certain kind and size, which are peculiar to the alternating strength alone. No doubt, they are not the direct cause of fatigue fracture, but it is possible that tiny intercrystalline scratches originate from the deformations of the crystals and produce considerable tensions as a result of the notch effect. If the alternating strength is great enough to enlarge the scratches permanently, the final result may be the fatigue fracture. Although this hypothesis is not by any means proved, there is the hope that further observations in the direction of this investigation will lead to greater knowledge of the nature of fatigue fracture.

* *Mitteilungen aus dem Kaiser-Wilhelm-Institut fur Eisenforschung zu Düsseldorf, vol. xx, No. 2.*

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Ferrous Metal Development

ALTHOUGH it can hardly be said that many new alloy discoveries have been made during the past year, unless we so classify a ferrous alloy containing 10% copper and 18% chromium, which is claimed to have a resistance to corrosion almost as high as the 18/8 stainless steel, considerable advances have been made in most branches of metallurgy. It is not proposed to deal with all these advances here, but to confine ourselves to a brief reference to some of the outstanding metallurgical developments in the iron and steel industry.

There has been improvement in steelmaking practice, particularly in the making of medium- and high-carbon steels. A fuller knowledge of the factors which control quality has led to more uniform furnace practice, increased the care and selection of the materials charged, and directed more attention to the importance of the slag. The need for some means to speed up the reactions in the open-hearth furnace has long been recognised, and the speeds obtained by the recently-developed Portevin process will, if the claims are substantiated, revolutionise the open-hearth process.

Mention has been made of improved quality, this applies to all grades of steel manufactured and is applied in a relative sense, since quality in regard to steel is very difficult to define, but high-grade steels are now being given an inclusions test as an indication of their manufacturing quality. Another important advance is the greater knowledge regarding grain size and the influence of grain growth in steel, but the significance of the term is not yet sufficiently familiar to the user. It is probable that eventually grain size will be regarded as one aspect of hardenability, a property to which a good deal of attention has also been directed during the past year.

Low-cost, low-alloy steels have made considerable progress as a result of metallurgical developments. Knowledge of the effects of specific alloying elements has increased, and high-tensile steels are now available in a useful range of properties to meet more stringent specifications than is possible with carbon steel of similar carbon content. Such elements as copper and phosphorus have provided new alloy combinations which increase tensile strength and also resistance to corrosion. Many of these low-alloy high-tensile steels have been developed, including copper-phosphorus, copper-chromium, nickel-copper, copper-molybdenum, manganese-copper, manganese-nickel, chromium-molybdenum, manganese-molybdenum, and several others in which two or more elements are included. In practically every case the total alloy content is under 4%, and often below 2%.

There has been great expansion in the application of heat-resisting and stainless steels, largely due to the development of improved or new alloys to meet special demands, but also as a result of improvements in manufacture, both as regards forms and sizes in which various steels are available and in quality. Knowledge of the various methods of manipulation and fabrication of these steels has advanced, and are used in all forms for plant of every description.

Attention may also be directed to another development in steel manufacture—i.e., a steel possessing improved machinability and designed for use in small parts which can be completed on automatics. Claims have long been made for easy machining steels containing a higher sulphur content than normal steels of similar carbon content, but recently a steel has been marketed in which lead is used as a constituent. It is claimed that the lead is so finely divided and so widely dispersed in the steel that it does not affect the properties of the steel, but has a remarkable effect in improving machinability.

As with steel manufacture, a gradual change is being effected in the steel foundry, production is now under better control, with the result that the products are of better quality and capable of improved service under more severe operating conditions. The same can be said of the low-alloy steel castings, which are being applied to an increased extent for structural purposes and especially for parts required to withstand wear and abrasion. There is a growing trend to save weight by making use of alloy steel castings possessing improved properties. Here again a wide range of alloys is used, but cost is frequently an important consideration, and the tendency is to favour the use of the less costly alloying elements, unless the parts are required for key positions, when the best available alloy for the particular service is generally considered to be the most economical, irrespective of the initial cost.

Many alloy steel castings are required to withstand various corrosive media, and although many alloys have been developed for this purpose those based on the 18/8 composition are probably the more regularly used for severe conditions of service, particularly since machining difficulties have now been largely overcome by metallurgical developments involving the addition of small percentages of other elements. Although many difficulties have been encountered with this alloy, the application of research soon provided solutions and incidentally a range of new alloys, based on the known corrosion resistant properties of the 18/8 alloy, which are more workable.

Better melting facilities and more accurate control, not only of the material charged and the actual melting, but of the various operations in the foundry, are responsible for considerable improvement in the production of iron castings. There has been a considerable increase in the properties of grey iron castings, and many foundries show that by exercising greater control castings are regularly produced in grey iron possessing properties which a short time ago were credited to alloy cast irons. But there has also been improvement in the production of the latter, and with proper heat-treatment some of these alloy cast irons compare favourably with steel castings. A number of years ago the iron foundry was in rather a bad way, and it was considered by many that keen competition of other products would seriously injure the iron-founding industry, but there has been an awakening, and to-day the iron foundry is in a more healthy condition than ever before.

Generally, improvements have been directed to cope with requirements demanded of ferrous materials, and while new compositions have been developed or the components of the older materials more carefully chosen, there has been an improvement in control technique to satisfy more stringent inspection, with the result that the quality of the products has been improved, and in the majority of cases control is so exercised that increased production will not involve any depreciation in quality. With a corresponding improvement in the political situation, resulting in the restoration of confidence, the iron and steel industry is admirably placed to participate in a trade recovery.

Physical Society's Exhibition

MANY interesting instruments and apparatus are exhibited at the Physical Society's Exhibition, which opened at South Kensington on January 3, among which are thickness meters by Salford Electrical Instruments, Ltd.—a subsidiary of the General Electric Co., Ltd.—which comprise a range of instruments for the measurement of the thickness of coatings of various non-magnetic types on magnetic bases. Operating from A.C. mains, these instruments enable the thickness of layers to be measured by placing an exploring head on the surface of the material, an indication being given directly on the dial of the instrument. They can be used with equal facility for measuring coatings on irregular objects, such as tanks, drums, etc., or on flat or corrugated sheets. Two types of instrument are available for thickness measurement—a general application type for measurement of sprayed metal, paint, enamel, etc., and other layers of medium thickness; and a sensitive type for measurement of very thin layers, such as tinplate or nickel-plating.

Another interesting exhibit is the "Teddington" automatic temperature controller, which is included in the display by the British Thermostat Co., Ltd., and is manufactured by this firm's associate company, Teddington Controls, Ltd. This controller is suitable for either electric or fuel-fired furnaces, the latter being regulated through magnetic or motor-operated valves. It is designed with movements suitable for any of the usual electrical heat-sensitive devices, such as resistance elements, thermo-couples, or radiation tubes.

This instrument is designed on the "chopper-bar" principle, but incorporates a patented construction in which two chopper-bars, driven by a single motor, operate a mercury-switch mounted on a balanced double-beam forming a parallelogram and having a single actuating plate. The control mechanism is characterised by the simplicity of its construction, the arrangement being such that positive operation of the mercury-switch is obtained with a negligible amount of force being transmitted to the measuring system. The minute amount of power required to give a positive positioning of the mercury-switch can be judged from the fact that the complete control mechanism can be driven by a small synchronous motor-consuming approximately 2·5 watts at 230 volts.

Intercrystalline Cracking of Boiler Steel and its Prevention

ONE of the most dangerous ills encountered in modern boiler plant operation is the intercrystalline cracking of the steel. This is caused by boiler water eating into the grain boundaries to form cracks so narrow that they frequently go completely through before they are visible. This has led to explosions and loss of life. Research conducted by the Bureau of Mines, United States Department of the Interior, in co-operation with other organisations since 1933 has demonstrated that this dangerous destruction is brought on by a complicated combination of factors. Concentration of the ordinary boiler water as much as a thousand fold is necessary. Ordinary water, not concentrated, does not cause cracking. The concentrated water will cause the cracking only when it contains a peculiar balance of corrosive and protective properties, to give a protective film over the grain faces of the metal, but with the grain boundaries exposed. A third essential factor, high stresses in the metal, must operate also if cracking is to proceed. To prevent intercrystalline cracking, certain organic chemicals have been found to be especially useful.

Based on these findings, a testing unit has been developed for measuring the intercrystalline attack that may be produced by any boiler water. This may be attached directly to the boiler or may be used in the laboratory. It will crack and break a steel specimen if the water is dangerous. The investigation is described in a recent lecture by Dr. W. C. Schroeder in the University of Maryland Bureau of Mines series.

Forthcoming Meetings

IRON AND STEEL INSTITUTE.

Jan. 18. Joint Meeting between the Manchester Metallurgical Society and Iron and Steel Institute in the Assembly Room, Blackfriars House, Blackfriars Street, Manchester, at 7-15 p.m. Mr. J. W. Rodgers will present his paper on "The Cold Deformation and Recrystallisation of Metal Crystals."

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Feb. 2. "Defects in Non-Ferrous Ingots," by G. W. Bailey, M.Sc.

LONDON SECTION.

Feb. 9. "Tin—its Extraction and Uses," by J. Macnaughton.

SWANSEA SECTION.

Feb. 14. "The Recovery from Waste Materials," by A. O. Thomas.

ROYAL AERONAUTICAL SOCIETY.

Feb. 7. "Sleeve-Valve Engines," by Dr. A. H. R. Fedden. Joint lecture with the Institute of Automobile Engineers.

Feb. 16. "Ignition Problems," by Dr. G. E. Bairsto.

INSTITUTE OF MARINE ENGINEERS.

Feb. 3. "High Speed Diesel Engines," by J. Calderwood, M.Sc., at the Sunderland Technical College.

Feb. 9. "Marine Steam and Diesel Main Machinery" by G. R. Hutchinson, in the Engineering Department of the University, Glasgow.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Feb. 3. "The Randupson Process," by F. W. Rowe, B.Sc.

EAST MIDLANDS BRANCH.

Jan. 28. "Some Notes on the Manufacture of Steel Castings," by C. D. Pollard, (at Derby).

Feb. 11. "More about Synthetic Sands," by A. Tipper, B.Sc. (at Loughborough).

LINCOLNSHIRE SECTION.

Jan. 23. "Thirty Years of Progress in Cast Iron," by A. B. Everest, Ph.D., B.Sc.

Feb. 13. "More Non-Ferrous Foundry Problems," by F. Dunleavy.

LANCASHIRE BRANCH.

Feb. 15. "The Manufacture and Application of Grinding Wheels."

BURNLEY SECTION.

Feb. 14. "The Production of Certain Iron Castings," by J. Roxburgh.

LONDON BRANCH.

Feb. 1. "Castings *v.* Welded Structures," a debate.

EAST ANGLIAN SECTION.

Jan. 19. "High Duty Cast Iron," by J. H. Williams.

MIDDLESBROUGH BRANCH.

Feb. 17. "Fifty Years Progress in Steel Moulding," by F. Swift.

NEWCASTLE-ON-TYNE BRANCH.

Jan. 28. "Sand Testing," by N. D. Ridsdale, F.C.S.

SCOTTISH BRANCH.

Feb. 11. "Melting Practice in a Large Engineering Iron Foundry," by W. W. Braidwood.

SHEFFIELD BRANCH.

Feb. 2. "Notes on Steel Foundry Practice," by S. Leetch.

WALES AND MONMOUTH BRANCH.

Feb. 4. "Some Jobbing Problems," by F. G. Jackson.

BRISTOL SECTION.

Jan. 21. "Moulding and Casting Propellers," by M. Wayman.

WEST RIDING BRANCH.

Feb. 11. "Alloy Cast Iron" by H. A. MacColl, B.Sc.

INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 20. "Machine Shop Practice." A Symposium of Papers by Nine Authors.

Jan. 23. "Corrosion," by K. Heywood, S.I.Mech.E. Graduates' Meeting.

Jan. 27. "High-Lift Safety Valves," by G. Sewell, A.F.C., A.M.I.Mech.E.

Feb. 3. "Cylinder Bore Wear," by Alex. Taub.

Feb. 10. "Brake Linings," by E. W. Sisman.

The Growth of Cast Iron and its Prevention

By J. D. Morgan, B.Sc.

Growth of cast iron as a result of repeated heatings is discussed, and an explanation given of the factors causing and controlling this defect. The requirements of growth-resisting iron are discussed, and reference made to irons which have growth-resisting qualities.

THE swelling and weakening which cast iron experiences on repeated heatings in oxidising atmospheres, commonly called "growth," has been a source of infinite trouble in many branches of engineering. It is responsible for the distortion and cracking of ingot moulds, carburising boxes, firebars, and furnace parts in general. In such cases the increase in volume may amount to more than 50%.

In a similar manner to other plain ferrous materials, heating cast iron in an oxidising atmosphere, especially if sulphur dioxide or similar impurities are present, results in the formation of surface scale. This oxide scale is permeable to gases, and tends to peel off, so that the underlying metal may still be attacked. In addition, if the cast iron contains large flakes of graphite, oxidation will proceed into the metal along these flakes, producing an increase in volume with a consequent weakening effect. The distortion is most pronounced in thin sections. In general, it commences rapidly, but the rate of growth decreases with time, even though ordinary surface oxidation continues. Alternate heating and cooling in certain ranges of temperature greatly enhances the trouble.

Growth cannot be explained in a simple manner. It is a complicated process, due to the effects of oxidation and gases at high temperatures. Opinion varies as to the relative parts played by the various factors causing and controlling growth. These factors are chiefly :—

(1) The decomposition of cementite.
(2) Repeated heating and cooling through the critical points.
(3) Occluded gases.
(4) Unequal expansion of the different constituents on heating.
(5) Internal oxidation.

The decomposition of cementite yields ferrite and graphite. As shown by Schiel,[1] this produces an expansion of 12·8%, a figure in good agreement with specific gravity calculations. In any casting the degree of expansion due to this decomposition depends on the amount of cementite in the iron. Since the change can only occur once, it probably causes but little damage in high quality iron. The presence of graphite is, however, indispensable if growth is to occur, so that decomposition of cementite, whether it occurs on completion of solidification or on reheating is of very great importance.

The effect of repeated heating and cooling through the critical points depends to a large extent on the material and the conditions of the treatment. On heating any ferrous material through its critical range, an abrupt dimensional change takes place, due to the transformation of body-centred ferrite to the denser face-centred austenite. If a temperature gradient is set up between the outer and inner parts of the casting, as happens during rapid heating or cooling, the outer layers transform sooner than the inner, so that internal stresses are induced. The capacity of the metal to resist these stresses depends on its ductility. Cast iron is not a ductile material, and its resistance to thermal stresses is not high. For this reason, therefore, rapid rates of heating and cooling are to be avoided, since the metal tends to spall. When such thermal stresses result in the formation of cracks, these appear to be located around the graphite lamellæ.

The coefficient of expansion of a gas is about 400 times that of cast iron. Cast iron may contain occluded gases, and the expansion of these on heating results in very large internal pressures tending to disrupt the metal. The influence of dissolved or occluded gases has been shown[2] to be unimportant when the silicon content is above 3%. Growth to the extent of 12% may occur in irons containing less than 1% silicon.

The differential expansion between the various micro-constituents, such as iron and graphite, results in stresses which may permanently deform the metal.

Oxidation is known to play a very important part in growth. It has been shown by Pearson[3] that alternate heating and cooling in a non-oxidising atmosphere usually results in very little growth. Kikuta[4] stated that the growth on the first heating was due to the decomposition of cementite present and on subsequent heatings to the differential expansion between the different micro-constituents, causing the formation of fissures in the region of the graphite plates—that growth being accelerated by oxidising conditions.

Grey cast irons contain the following main constituents—viz., ferrite solid solution, pearlite, graphite, and phosphide eutectic. Of these, only ferrite and graphite need be considered, for on repeated heatings pearlite decomposes to ferrite and graphite, whilst only low-grade irons contain appreciable amounts of the phosphide eutectic.

When such a grey iron is heated, it undergoes surface oxidation, whilst the oxidising gases also diffuse into the interior through fissures and channels between the ferrite and graphite. Such fissures are present by reason of the stresses set up during the heating process, as described above. Oxidation of the metal around the graphite flakes then ensues. Since the oxidation products—ferric oxide, silica, manganous oxide, and phosphorus pentoxide—occupy a larger volume than their parent substance—ferrite—permanent expansion is the result. According to Thyssen,[5] the oxidation products form a wedge in the original fissures, and thus facilitate further fissuring. According to Carpenter[2] some attack is produced by the action of carbon dioxide on the silicon in solution in the ferrite. The theory of internal oxidation satisfactorily explains the phenomenon of growth, but the other factors previously mentioned are contributory to the main effect.

The factors affecting growth may now be classified as follows :—

(1) *Temperature.*—The extent of the cracks formed and the activity of the furnace gases in producing oxidation are greater the higher the temperature above 500° C.

(2) *Size, Amount, and Distribution of Graphite.*—The larger the flakes and the greater the amount, the greater the growth. Resistance to growth is greater the more isolated from one another are tke flakes.

1 F. Scheil. *Arch. Eisenhutt.* 1932, 33, 6, 66.

2 H. C. H. Carpenter. *J. I. & S. I.* 1911, 83, 1, p. 196.
3 Pearson. *I. & S. I.* Carnegie Schol. Mem. 1926, 15, p. 297.
4 Kikuta. *Sci. Repts.* Tohuku Imp. Univ. April, 1922. Vol. XI, p. 1.
5 Thyssen. *J. I. & S. I.* 1934, 130, 153.

(3) *Intrinsic Resistance to Oxidation of the Metal.*—The greater this resistance, which may be increased by suitable alloying metals, the greater is the resistance to growth.

(4) *Strength and Ductility at High Temperatures* (500°–800° C.).—These properties control the fissures which result from rapid heating and cooling through the critical range and the differential expansion between different constituents.

(5) *Stability of the Carbides.*—This controls the amount of graphite formed.

From the above, it follows that the requirements of a growth-resisting iron are :—

(1) A small amount of finely dispersed graphite.
(2) Inherent resistance to oxidation.
(3) Ductility and strength at high temperatures.
(4) Stable carbides.
(5) Absence of a critical range within the temperature range of use.

Many methods have been adopted to obtain growth-resisting irons, and the degree of success depends upon the method and its cost. In many cases a satisfactory degree of growth resistance is attained relatively cheaply, whilst for another application the iron would be little better than ordinary grey iron.

Control of graphite size and distribution is attained by careful melting and casting and by inoculation. Control of the melting and casting operations results in improved mechanical properties. Inoculation consists of melting a synthetic iron carbon alloy or low silicon alloy in the electric furnace (rotary or Heroult arc), oil-fired rotary furnaces or carefully controlled cupolas. Before casting the metal is then inoculated with a small amount of ferro-silicon, calcium silicide, or some such other substance which will produce a large number of finely dispersed nuclei for crystallisation of the graphite. Higher temperatures than those attained in ordinary cupola practice are desirable, and stewing of the metal is practised in order to float off the non-metallics before inoculation is carried out.

Requirements (2) to (5), listed above, may be attained by the use of alloying elements, and the control of silicon. Growth-resisting irons may therefore be classified as :—

(1) White cast irons.
(2) Low silicon irons.
(3) High silicon irons.
(4) Austenitic irons.

White irons are free from graphite, and as such are resistant to growth. The temperature conditions under which they may be used depend upon the stability of the cementite, and it is therefore the practice to add to the iron a suitable percentage of chromium (1%) or some other carbide stabiliser. The mechanical properties, however, are poor, and so the iron may only be used for comparatively unstressed articles. Local chilling of the surface of grey irons by the use of chills in the mould is often utilised to prevent surface cracks in low temperature work.

The term low silicon iron might be supposed to include white irons, which must be low in silicon to prevent graphitisation, but in connection with growth it includes any iron of low silicon content. Irons which consist of a fine graphite structure are in this class, since a low silicon content is necessary for the fine structure. A fine structure may, however, be obtained by control of the melting conditions as discussed previously, a low silicon iron resulting. In this type of iron graphite is not necessarily eliminated, whilst the critical points are still present, and so the iron is not completely resistant to growth.

Whilst Andrew and Hyman[6] showed that silicon increases the tendency to growth by reason of its graphitising influence, Norbury and Morgan[7] have shown that amounts of silicon in excess of 4% diminish growth. A group of growth-resisting irons, known as "Silal," and containing 5–10% silicon, are available. The graphite in these irons is in a finely divided state, and growth resistance is due chiefly to the high critical points consequent on the high silicon content. The silicon also confers inherent resistance to oxidation, which is also sometimes increased by the addition of aluminium (2%). Addition of aluminium also improves the mechanical properties, for high silicon irons are brittle.

In the austenitic irons it appears that the five desirable growth-resisting properties may be attained, but they form the most expensive type of cast iron. The austenitic state is attained by a combination of nickel and copper, whilst chromium is added to confer resistance to oxidation. The alloy can be cast with a fine graphite structure ; it is tough, since it is austenitic and contains nickel ; and also, since it is austenitic, it has no critical points. Despite the cost of the alloy, the excellent properties seem to warrant its use in many cases where heat resistance is desired, economic satisfaction being attained by reason of its long life. Typical irons are "Ni-resist," containing 2·7–3·1% carbon, 1·2–2·0% silicon, 12–15% nickel, 5–7% copper, and 1·5–4·0% chromium ; and Nicro-silal, containing 1·8% carbon, 6% silicon, 1% manganese, 18% nickel, and 2% chromium.

When the iron is to be used only at low temperatures, an ordinary grey iron may be used. In this case any growth is probably due to decomposition of pearlite into ferrite and graphite. By subjecting the rough casting to a prolonged low temperature annealing (5 days at 650° C.), before machining, satisfactory performance is attained.

6 Andrew and Hyman. *J. I. & S. I.* 1929, 109, 451.
7 Norbury and Morgan. *J. I. & S. I.* 1931, 123, 413.

Restrainers in Acid Pickling

THE latest information on the use of a well-known range of restrainers for acid pickling, with a practical and simply written account of the theory and practice of pickling generally, and the part played by restrainers in particular, has recently been published.* The products which it describes show the extent to which pickling processes have been rationalised. Acid pickling has now fallen into line with other branches of metal finishing, and make use of standardised chemicals, scientifically designed for the purpose, and used in an accurately controlled process.

Some figures in the introductory sections give a clear indication of how much good metal may be wasted by arbitrary methods of descaling. In the removal of 6 lb. of scale from 1,000 sq. ft. of steel, for example, as much as 65 lb. of metal may be irreclaimably dissolved : and 120 lb. of acid may be used up in dissolving it, although only 11 lb. are required to do the useful work. In addition, there are discussed the secondary effects of acid brittleness and blistering of sheet and strip due to excessive evolution of hydrogen, the roughening and pitting of steel, with consequent loss of tensile strength, and the damage to factory fabric caused by acid spraying. All these facts point to the need for a reliable method of controlling acid pickling, so that metal and acid consumption are reduced without slowing up the descaling process.

Even if pickling were to be so carefully supervised that the metal was never left in the acid longer than was absolutely necessary for descaling, there would still be a need for restrainers. This is indicated by a series of photomicrographs, comparing the surface structure of various types of steel after pickling in 2% sulphuric acid, with and without one of the restrainers described.

The book deals in practical detail with specific restrainers and their use. Each restrainer in the range has been designed for a specific purpose, such as for use with sulphuric, hydrochloric or nitric acids, or for pickling at low or high temperatures. Some of them are powders and some liquids, and both foaming and non-foaming types are represented. Complete dosage figures for these restrainers, covering a wide range of pickling baths are given. Tables of comparative temperature and hydrometer scales complete a combined handbook and works manual which should be in the hands of every metal finisher.

* "Galvene and A.C.P. Rodines." I.C.I., Ltd. Third Edition. Pp. 19.

Progress in the Non-Ferrous Metals Industry

Rigid production control and uniformity of quality of materials are becoming increasingly important in the development of the non-ferrous industry. In addition, however, manufacturing technique has advanced, and new equipment has been installed during the past year to increase production facilities. In this article brief reference is made to some of the developments.

THE needs of the engineering industry continue to make increasing demands on metallurgical progress which, only about ten years ago, would have been considered difficult or incapable of accomplishment, as far as non-ferrous alloys are concerned. With regard to the question of non-ferrous alloys for bearing requirements, progress has to keep pace with the rapid development which has taken place in the production of high-grade steels.

The general tendency in many branches of engineering, especially in connection with aircraft and motor-car production is in nearly all circumstances to reduce weight and increase efficiency. This has resulted in the establishment of increasing numbers of Government and British Standard Specifications to ensure a very rigid production control and uniformity of quality of materials, testing facilities having, in consequence, become an everyday feature of production control, and tests such as proof stress and impact tests are now in more general use. An important feature relating to the automobile industry is that the production of higher grade cars each year, in regard to quality, performance and efficiency, with a tendency towards decreasing prices, notwithstanding higher production costs, has made it essential for manufacturers to explore every avenue likely to result in more efficient production. When it is considered that to-day's production costs in all branches of industry are appreciably higher than a few years ago, due to higher taxation, wage award increases, holidays with pay, etc., it will be realised how great is the need to ensure the greatest possible efficiency and the least possible waste.

Progress in non-ferrous research is not confined to any one phase of industry. Progress in regard to the heavy industries is equally great. The demand to-day for high-grade alloys for every conceivable purpose is very marked, and includes development of acid-resisting alloys which were only in the embryo stage some few years ago. Hydraulics have also played an important part, and alloys of various types and in various forms are to-day produced as a matter of course to withstand pressures which would have been the subject of real concern in past years.

The outlook for the future is towards increasing development at a cumulatively rapid rate, and it would appear that firms exploiting the manufacture of non-ferrous alloys will survive only according to the efficiency of their production control, necessitating ever-increasing laboratory technical equipment.

ALUMINIUM DEVELOPMENT

The aluminium industry reports another record year. Demand from the aircraft and other armament industries has arisen and is increasing steadily, and new applications for aluminium are helping to counteract some falling off in demand from civil industry. Thus, although the price of ingots was reduced in July last, ingot manufacturers have been able to make up on increased production what they have lost through lower prices.

The main directions in which the use of aluminium and aluminium alloys has been developed by the British Aluminium Co. Ltd. during the past year are given in the following notes :—

Brytal Treatment.—This process has now been in operation for several years, and certain manufacturers who are licensees for the process have built up a satisfactory business in Brytal-treated metal for reflectors. The metal is being used for both light and heat reflection, and is giving a high degree of satisfaction in commercial work. Tests carried out by us show that the percentage increase in reflectivity is very closely connected with metal purity. Commercial metal is improved in reflectivity by the process and gives a particularly good finish where a semi-diffused reflection is required, but the highest specular reflectivity is obtained by working with special grades of metal which we have developed for the purpose.

The highest degree of reflectivity—about 84% absolute, of which only about 0·5% is diffuse—is obtained by the use of super-purity aluminium, 99·99% minimum purity.

Machining Alloys.—BA/35 alloy has made considerable strides during the past twelve months, not only because of its good machining qualities, but also because the saving is considerable when a white metal finish is required, since the use of an aluminium alloy obviates the necessity of plating. The metal has been approved by the air Ministry for manufacture of machined aircraft parts, and a provisional specification, No. DTD 368, has been drafted. While the alloy is normally supplied in extruded forms only—i.e., as machine and bar stock, tests have also been made with a view to producing hot pressings in the alloy.

Aluminium-alloy Glazing Bars.—The development of aluminium-alloy glazing bars has followed closely on the production of medium-strength aluminium-magnesium alloys which can be produced by simple extrusion. Initial tests on this subject were commenced in 1934, and it was found that satisfactory results were obtained both from the point of view of strength and length of life. As a result of these tests, aluminium-alloy glazing bars are now installed in a large number of instances, and are giving full satisfaction.

"*Imprest*" *Sheet.*—"Imprest" sheet is obtained by a special form of rolling, so that a matt finish can be obtained on parts of the sheet, other parts remaining in bright finish. Many attractive designs can thus be obtained, and the material is finding a ready sale in many directions. Typical applications for which this material has been adopted include decorative purposes in architecture, manufacture of trays and similar domestic articles, clock dials, and a variety of products where an attractive appearance of this type is of first importance.

Alloys and Applications

In the aircraft industry Northern Aluminium Co. Ltd. report the increasing application of Alclad during 1938. It constitutes the main structural material of the Armstrong-Whitworth "Ensign" air liners, the new De Havilland transport "DH 95," the Mayo composite aircraft, the Short "Empire," and other flying-boats, and in the military category, the Bristol "Blenheim," Hawker "Hurricane," Short "Sunderland," Blackburn "Skua," Fairy "Battle," Gloucester "F 5/34," and

Handley-Page "Hampden," amongst many others. It is also of interest to record that this alloy has been supplied to one of the most important aircraft constructors for use in the construction of a new machine, and that the equipment of this particular factory has been planned specially to make use of the alloy in the solution heat-treated temper, the only other treatment to which it is subjected being the subsequent low-temperature precipitation treatment.

Alclad NA 23S to DTD Specification 390 has recently been developed to replace Alclad NA 17ST to Specification L 38, NA 24ST to Specification DTD 270 and Alclad NA 24ST to Specification DTD 275. The mechanical properties of the new alloy are intermediate between those given by the three alloys which it replaces, the intention being to reduce as far as possible redundant alloys, and concentrate production on an Alclad alloy, which demand indicates and fulfils the requirements of the aircraft industry. There has been an increasing demand for medium-strength, strain-hardened alloys, such as NA 57S to Specification DTD 292 and 296 for aircraft construction, some of which has been used to replace the heat-treated alloys for the stressed-skin coverings of aircraft. Extruded sections in NA 26S alloy to Specification DTD 364, with its high proof stress of 26 tons per square inch, are being used in increasing quantities for aircraft construction.

There has been a definite increase in the demand for alloys for road transport-vehicle construction, particularly in respect of underframes for drop-side vehicles and pantechnicons. The essential requirement that sound alloys having the necessary mechanical and other properties shall be available at a price which makes the adoption of light alloys a reasonable alternative to the heavier steel and timber construction, has been achieved to a very marked extent. In this development, NA 4S sheet with an ultimate strength of 13·5 to 16 tons per sq. in., and NA 13S alloy extrusions have played a considerable part. The sphere of aluminium continues to expand in the architectural field.

Castings and Forgings.—The development work undertaken on castings and forgings during the last two or three years has borne fruit during 1938 in the aircraft, road transport and electrical industries where the high-strength casting alloys have found widespread adoption. The use of the heat-treated alloys, and in particular LO-EX alloy for large Diesel pistons has been firmly established, individual pistons weighing up to 400 lb. having been supplied for marine engines of this type.

In the motor industry aluminium pistons continue to find new users. LO-EX alloy is being used extensively for such pistons, the finished pistons frequently being treated by the anodic process, or by the more-recently-developed tin-plating process. An interesting application of aluminium alloys in this field is the foundation piece of the Albion five- to six-ton chassis KL/127. This casting weighs approximately 30 lb., and is believed to be one of the largest gravity die-castings supplied to the motor industry.

Manufacturing Plant

By the use of the new giant extrusion press, the Northern Aluminium Co., Ltd., is producing considerably larger sections than hitherto available. Such sections can be supplied in lengths adequate for such parts as aircraft wing spars, crane booms, railway structures, architectural sections, etc. Previously shorter lengths of sections have had to be used involving greater weight and additional labour costs. The building up of composite sections can now be eliminated. Very large forging stock billets also are now being produced in the new extrusion press.

In extension of the facilities for sheet production, a new British-built reversing two-high hot mill will shortly be in operation, embodying the latest developments in control, together with the most up-to-date cold-rolling equipment, furnaces and so on, which will represent a very large increase in the output of sheet products, some of which will be in forms hitherto unobtainable.

The completion of a further laboratory and installation of additional X-ray and other apparatus for research and investigational work has proceeded collaterally with the increasing output and will assist in ensuring a continuity of supply of products of the highest grade.

The forging equipment at the Birmingham works, which includes in particular a 10-ton hammer with ancillary equipment in the form of hydraulic upsetting presses and heat-treatment equipment, completion of which was effected towards the end of last year, is now in full production, mainly on propellor blades to very close-dimensional tolerances with consequent reduction in finish machining, in addition to the upset pistons mentioned above.

Attention may also be directed to the large press, to the design of the Loewy Engineering Co. Ltd., of London, being erected at the Tyseley Works, Birmingham, of the Reynolds Tube Co. Ltd. This is claimed to be the largest press in the world for extruding light metal alloys, and will be employed in the production of larger extruded sections of greater length than present facilities permit. This installation, together with other developments associated with it are costing about £250,000.

MAGNESIUM DEVELOPMENTS

Manufacturing Processes and Alloys

A recent development in "Elektron" sheet materials is reported by Magnesium Elektron Ltd. This is the production of a sheet alloy known as AM 537, with mechanical properties equivalent, in some cases well above, those laid down in Specification DTD 120A. In addition to this, the material can be cold worked to some extent, having elongation of 18%, and can be bent cold over a radius of four times sheet thickness. The alloy has good welding properties for open seams and can be used in cases where higher mechanical properties than those required under Specification DTD 118, and enhanced rigidity, are desired. The great advantage of AM 537 over DTD 120A lies in its remarkable resistance to corrosion. Developments in the use of "Elektron" sheet include the fabrication of monocoque fuselages and other major components. One aircraft firm has recently put on the market a small two-seater training aircraft, the fuselage of which is made completely from "Elektron" sheet and which is claimed to be extremely cheap and easy to produce. Other components now fabricated commonly in "Elektron" sheet include fuel and oil tanks, fairings, cowlings, wing structure, control surfaces, seats, etc.

Recent forging developments have led to a great expansion in the use of "Elektron." Mechanical figures of 12% elongation, 14 tons per sq. in. proof and 20 tons per sq. in. ultimate tensile have been attained with regularity. The forgings are being used in the aircraft industry particularly, to a great extent for airscrew blades, engine bearers, control levers, etc., these components allowing of full advantage being taken of the high strength-weight ratio of the material.

Developments in the application of castings have also been rapid in the last 12 months. The tendency in this connection is to replace complicated and costly joints and components normally fabricated from sheet and strip riveted up, by a single casting. A very great advantage is obtained in cost and manufacturing time.

Installation of New Plant

The production of magnesium and "Elektron" alloys, which began in December, 1936, at the Clifton Junction Works of Magnesium Elektron Ltd., was considerably augmented in the early months of 1938. Large extensions which have been erected during 1937 were then put into operation to make this plant one of the largest and most modern magnesium-producing units in the world. The power is supplied by the Lancashire Electric Power Company: the raw materials are at present imported,

but much progress has been made during the year in the development of domestic resources, and it is expected that during 1939 considerable quantities of magnesium will be made from domestic raw materials. The plant produces all the "Elektron" alloys in ingot and billet form, and, in addition has a magnesium powder plant in full operation.

Progress and Possible Trends

Magnesium production in Great Britain is estimated at nearly 7,000 tons per annum, the large increase over former years being due to the fact that the Clifton Junction Work of Magnesium Elektron Ltd., are now working at capacity. The trend of the magnesium industry is definitely towards expansion. There are three reasons for this: Firsts, the intrinsic value of lightness (40% lighter than aluminium) in a constructional metal; secondly, the possibility of substituting magnesium for metals less readily available; thirdly, the possibility of establishing indigenous production owing to the wide distribution of the basic raw materials. This last factor, which explains the rapid growth of the industry in Germany, Italy and Japan, may not be without influence on future developments in Great Britain, where large deposits of magnesium-bearing dolomite are available.

COPPER ALLOYS

Metallurgical developments regarding copper alloys during 1938 have been considered very fully by Miller* therefore attention will be directed to the activities of some firms specialising in the production of copper alloys and basic products from these alloys. The almost limitless application of extruded rods, both solid and hollow, and sections in brasses, bronzes, white metal and copper, with its consequent saving in production costs, is being more widely appreciated every day, and numerous non-ferrous parts formerly cast are now being produced more economically and efficiently from extruded rods and sections. To meet increasing demand, for instance, McKechnie Brothers Ltd. have erected a new foundry in order to increase their output of gunmetal, phosphor bronze, manganese bronze, brass, nickel silver and manganese-copper ingots. In addition, this firm installed another extrusion press during the year—one of the latest and most modern of this type of machine—to enable it to keep pace with the continually increasing demand for extruded rods and sections.

An increasing demand for extruded sections is also reported by the Delta Metal Co. Ltd., who state that, although they possess dies for many thousands of shapes, new types and sizes of extruded sections are being made continually. The degree of accuracy to which extruded rods and sections can be made renders machining unnecessary in many instances, and reduces the percentage of waste to a minimum. Particular reference is made to the increase in the use of metal mouldings for ship decoration; following the satisfactory results of these mouldings in the decorative scheme on R.M.S. *Queen Mary*, these materials have again been specified for similar work on R.M.S. *Queen Elizabeth* and R.M.S. *Mauretania*.

A new application for copper alloys with the strength of steel which do not rust or corrode has arisen in the building of air-raid shelters. Here the materials used have to give service in situations which are damp and generally favourable to deterioration from corrosion. In consequence steel bolts and nuts, both for timber and concrete constructions are likely to suffer loss of strength; this is claimed to be obviated by the use of Delta Bronze No. IV. This metal is also suitable for the manufacture of such fittings as brackets and supports for seats, hinges and bolts, etc., for gas-proof doors, angles, tees, etc. for door frames, as well as for lighting fittings.

Bronzes

The activities of the Holfos Works of John Holroyd and Co. Ltd., are limited to metals of the phosphor-bronze and gunmetal type. During the past year this firm has developed its plant and buildings, and in fact the foundry is still in process of being entirely rebuilt. The firm reports continued and increasing demand from first-class engineering firms for sounder and harder-wearing bronzes, and it is claimed that the centrifugal process is undoubtedly the method to be employed to meet this demand. For many years John Holroyds have cast worm-wheel blanks, rings and similar components by this method, but of more recent years they have developed the process of casting tubes centrifugally. Their patented spuncast process is now being worked abroad by important firms in Australia, Germany, France, Poland, Belgium and Sweden, and they also have three licensees in this country who are operating the process for purposes which do not conflict with their own interests. In addition, negotiations have been entered into to licence further firms of very high standard at home and abroad.

In addition to progress in the demand for bronzes and brasses in various marketed forms, the Manganese Bronze and Brass Co. Ltd. report great progress in the application of "Oiliete" bearings. These are self-lubricating bronze bearings which are porous in texture to permit their impregnation with lubricating oil of appropriate quality. Recently, this firm published an information booklet dealing with these self-lubricating bronze bearings.

Since the Phosphor Bronze Co. Ltd. was taken over by Messrs. Hardy Spicer and Co. Ltd., of Wilton, Birmingham, just over a year ago, a complete plant reorganisation has been effected with the object of ensuring that, in addition to specialised research work, production is operated on a basis incorporating the latest developments. The latter include the installation of specialised forms of melting practice according to the type of alloy involved. The range of bronzes manufactured contain a high phosphorus content, which is definitely a constituent of the alloys as well as a de-oxidising agent. It is generally recognised that the successful manipulation of a high phosphorus content involves not only its four special melting technique, but a rigorous control of sand, loam and other materials used for moulding, and necessitates a specialist.

Shops in this plant are equipped to deal with the production of gear bronzes in all forms, including sand, chill and centrifugal castings. A special feature is made of the production of centrifugal castings, provision for which includes the latest type of centrifugal casting plant. The modernised installation also includes the latest pneumatic equipment for efficient and speedy dressing of castings, whilst modern sand-blasting equipment has been installed in order to turn out castings possessing a high finish.

The resources of Hardy Spicer and Co. Ltd. and the Phosphor Bronze Co. Ltd. have been pooled in regard to laboratory control and testing facilities. It is also understood that the Phosphor Bronze Co. Ltd., with foundries and machine shops at Chester Street, Aston, Birmingham, Birch Road, Witton, Birmingham, and Sumner Street, London, are already putting into effect further extensions in connection with production at Birch Road, Witton, Birmingham, to which address the registered office will shortly be transferred from 54, St. Thomas Street, London, S.W. 1.

Copper Materials in the Building Industry

Some of the most important non-ferrous metal developments of recent years have concerned their various and increasing uses in building practice. A notable example is copper, which has found many new building uses, not only in the form of its most recently developed alloys for such fittings as domestic water and gas services, calorifiers, boilers and storage tanks, but also in the form of sheet and strip for roofings, flashing, guttering, and damp-proof courses. Copper is also now largely used for expansion jointing for concrete structures, particularly in road and bridge work, and all jobs involving large expanses of concrete. These developments of copper, reported by I.C.I.

*H. J. Miller, *Metallurgia*, Dec., 1938.

Metals Ltd., are a result not only of the intrinsic qualities of the metal and its alloys, but also of its ease of working, and of the fact that modern methods of manufacture have made it available in strip form in coils of convenient standard lengths and widths.

These advantages are particularly evident where copper strip is used for damp-proof courses. It is, of course, impervious to moisture and thick enough to resist damage by sharp grit. It fulfils structural requirements also in that it will not yield under load, nor stretch or tear if movement occurs in the brickwork. Finally, it is not liable to buckle, and it is easy to handle: strip can be quite simply unrolled on to mortar, to which it will adhere readily.

Copper is inherently resistant to corrosion, and tubes of it can be relied upon to retain an unimpaired surface inside and out under most severe conditions. Copper piping has therefore long been used for domestic water services, and buried copper tubes in use for this purpose for over 40 years have shown no sign of deterioration. Actually, it would be truer to say that copper tubes do not rust, because the surface film formed as a result of the very slight corrosion in ordinary water acts as a protection against any further corrosion effect. Modern technique of copper-tube manufacture has made these available not only in a very wide range of gauges at a reasonable price, but also with a very smooth bore, so that, size for size, modern copper piping delivers a greater volume of water than piping in other metals.

For gas services, copper tubes, in comparison with steel tubing, provide less risk of stoppages due to internal corrosion, and meters last longer being free from dust and corrosion products from the tubes. Moreover, the very smooth bore prevents loss of pressure due to frictional resistance to flow. Modern methods of manufacture to very close tolerances, and to an increased accuracy of diameter and gauge, have made copper pipes readily interchangeable and suitable for use with any type of fitting.

An important extension of the application of copper tubes to domestic gas and water services is their use for conduit systems for electric wiring. A notable example is the new "Broduit" system, developed by I.C.I. Metals Ltd., which consists of light gauge copper conduits and copper junction and switch-boxes, making a complete copper conduit system. In addition to ease of installation and more certain mechanical and electrical continuity, the new system offers many advantages over steel tubes for electrical conduit work, notably absence of corrosion and reduced weight per foot run. In fact, the saving in weight has been calculated as approximately 40%, compared with solid-drawn steel tubes. The need for resistance to corrosion is particularly urgent during and immediately following the construction of a building when it is drying out, and conduits are wholly or partially filled with water. Moreover, internal rusting has a very damaging effect on the insulation of the cable, and, since it leaves the inside of the conduit rough, greatly increases the friction where the wires are dragged against it. The current capacity of conduits of this type is as much as 50%.

Among the recently developed alloys of copper, the copper-silicon manganese alloy known as "Everdur," has found increasing use for such fittings as hot-water storage tanks and cylinders. This alloy combines the corrosion resistance of copper with the strength of medium carbon steel. Mention may also be made to the growing use of copper as a decorative material. Copper is one of the most beautiful of metals, polishing well, and, on exposure to the atmosphere, gradually toning down in colour to the appearance of bronze.

New Non-Ferrous Works at Bilston, Staffordshire

A sign of continued advancement in the demand for non-ferrous tubes is evident in the start of manufacture at the works of the Wednesbury Tube Co. Ltd. which has a long association with the welded steel tube trade. Associated with this firm is a branch works engaged in manufacture of lead pipes. The new works at Bilston, adjacent to the welded-tube department has been designed, laid out, erected and started up under expert advice for production mainly of material used in the erection of domestic equipment, and at the present is concentrated on production of copper tubes from about 1½ in. down. Provision has been made for future additions of plant as may be required to meet demands. The whole plant, apart from the casting shop is contained in the main building which is 300–0″ long by 60–0″ wide. The melting and casting department is equipped with a battery of gas-heated melting furnaces—Morgan-type tilting of 650-lb. capacity, supplied with gas from the local main. An electric melting furnace is also installed. Large numbers of cannon-type moulds of varying diameters and capacities are temporarily arranged on revolving table.

The gas reheating furnace for billets for extrusion is by Liptak, capable of being raised to any desired temperature up to 1,200° C., and is provided with an electrically-controlled pusher arrangement for controlling progress of billets through heating chamber. A 1,000-ton vertical extrusion press with sliding container, by Fielding and Platt Ltd., of Gloucester, is set on ground level with delivery chamber below the mill working level. A set of three-throw Fielding and Platt Ltd. horizontal pumps working in conjunction with compressed-air accumulators supplies the operating power. A comprehensive battery of chain benches totalling nine chains, comprising single and double chains, and, in the case of the single chains, arranged to be available for plug- or bar-drawing wire built by Fisher and Humphries, Pershore, Worcestershire. These benches are each separately driven by electric motors, and are capable of being operated at two and three different chain speeds through the most modern speed-boxes. An annealing muffle of the Liptak type, heated by town gas is equipped with an electrically-controlled automatic charging and discharging machine, and this furnace and the reheating furnace is under automatic temperature control. The installation is very modern and capable of a high output.

Use of Nickel Sulphate in Electro-Plating

THE application of plating is increasing rapidly, and some people consider that its extension in the future will be used to protect from corrosion all iron, copper, or zinc alloys used. It is assumed, however, that the public will tire of the colour and appearance of nickel and chromium-plated articles. To meet the need for a variety of finishes, black nickel, an electro-deposited alloy containing nickel, zinc, and sulphur is being used over white nickel-plate for certain applications. An electro-plating process which will coat nickel-plated articles any colour of the spectrum is also now available.

Nickel sulphate, manufactured as a by-product of electrolytic copper refining, is the cheapest and most readily obtainable water-soluble compound of nickel, and has been the compound most used in nickel-plating. The plating is carried on in wood or earthenware tanks, or in steel tanks lined with rubber or lead, the modern trend being toward rubber-lined steel tanks.

Many nickel-plated articles are subsequently chromium-plated. This extra operation not only enhances the appearance of the article, but helps make more lasting the beauty of the finish, because of the hardness of the chromium and its non-tarnishing properties. Contrary to early predictions, the advent of commercial chromium-plating has not lessened the amount of nickel and nickel sulphate used in plating, but rather by overcoming one of the objections to straight nickel-plating, has greatly expanded the field for nickel-chromium finish.

Relationship Between the Mechanical Properties and Results in Service

By L. W. Schuster, M.A.

None of the properties determined in the most commonly adopted mechanical tests is an important factor in causing a normal failure of service. The usual failure is due to faulty design or work-manship, carelessness in operation, or such causes as torsional or other forms of vibration. In this article failure of parts following fusion welding repairs, corrosion fatigue, torsional vibration, longitudinal tests, and failure from induced brittleness are discussed in relation to results in service.

THOUGH I could give innumerable examples of the failure of parts due to their having been repaired by fusion welding, I shall refrain from doing so, as this form of repair, when skilfully carried out, does on occasion prove to be an invaluable asset to the engineer, and I do not wish to give any impression that I am in principle opposed to repairs by welding. I will, however, merely remark that experience shows that great caution is required before parts subjected to fatigue stress are repaired in this manner, and will give examples of only two particular types of failure of welded parts.

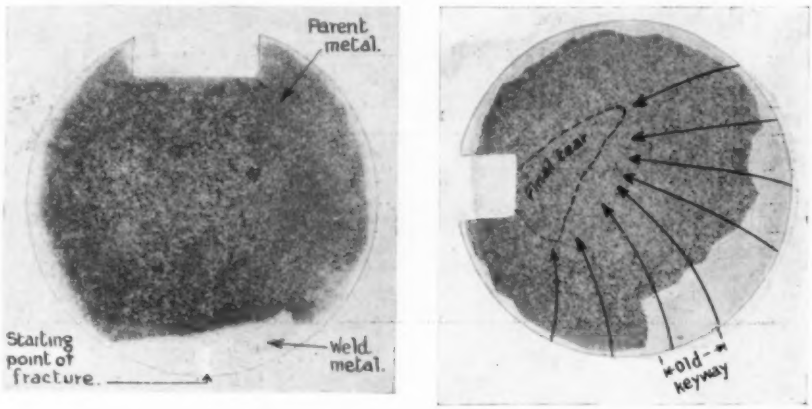


Fig. 27.—Sulphur prints of two motor shafts which had failed, showing the weld- and parent-metal and the starting points of each fracture.

The first refers to the building-up of shafts on account of wear at the seat of a pulley or gear wheel, or say in order to fit a new pulley with a boss having a bore slightly larger than that of the pulley previously fitted. Numerous examples have been experienced where the deposition of metal in this manner has led to disaster, owing largely to the resulting internal stress, and the comparatively low fatigue range of the deposited weld metal and the metal at junctions; the feature usually noticeable is the tendency for failure to commence at the part or parts at which the added metal is deepest, say at a part where an old keyway has been filled up. Such failures occur whether the weld metal is of good or of bad quality. A few illustrations, by means of sulphur prints, is the simplest means of making evident the difference between the weld- and the parent-metal. These failures all took place under fatigue within a year of the repair, and it is to be borne in mind that whereas the fatigue strength of the parent metal may be ± 15 t./sq. in., it is highly probable that at some point or other, at the surface of the weld metal, the metal will have a fatigue strength not exceeding ± 8 t./sq. in.

Fig. 27 shows two motor shafts. In the shaft at the left, fracture definitely travels from the welded-up keyway and finishes at the next keyway. In the shaft at the right, fracture starts from several points on the circumference, mostly in the region of the added metal, and finishes near the new keyway.

Fig. 28 refers to the shaft of a gas engine and shows a fracture that took place just outside the flywheel, the shaft having had a ring shrunk on to it at this part. The course of fracture has been marked in by arrows, and it is obvious that the general direction of failure is from the old to the new keyways. A sulphur print of a cross section close to the fracture showed that the fracture had travelled from the part where the greatest depth of metal had been deposited, i.e., at the old keyways.

A piston rod that failed in a similar manner is shown in Fig. 30, weld metal having been deposited at the surface, owing to looseness within the crosshead, the position of the fracture being marked on. In the illustration at the top of Fig. 31 is shown one of the surfaces of fracture, and it is to be seen that independent cracks had broken out at three positions marked A, B, and C. The sulphur print at the bottom was taken as close as possible to the fracture, but the distance away naturally varied at different points. It shows that the depth of the deposited weld metal, which had been laid in longitudinal runs, was irregular. The first crack, A, however starts in line with the deepest and largest layer of weld metal. Similarly C corresponds exactly with a deep run. The depth of metal at B does

Fig. 28.—Shaft of a gas engine showing fracture.

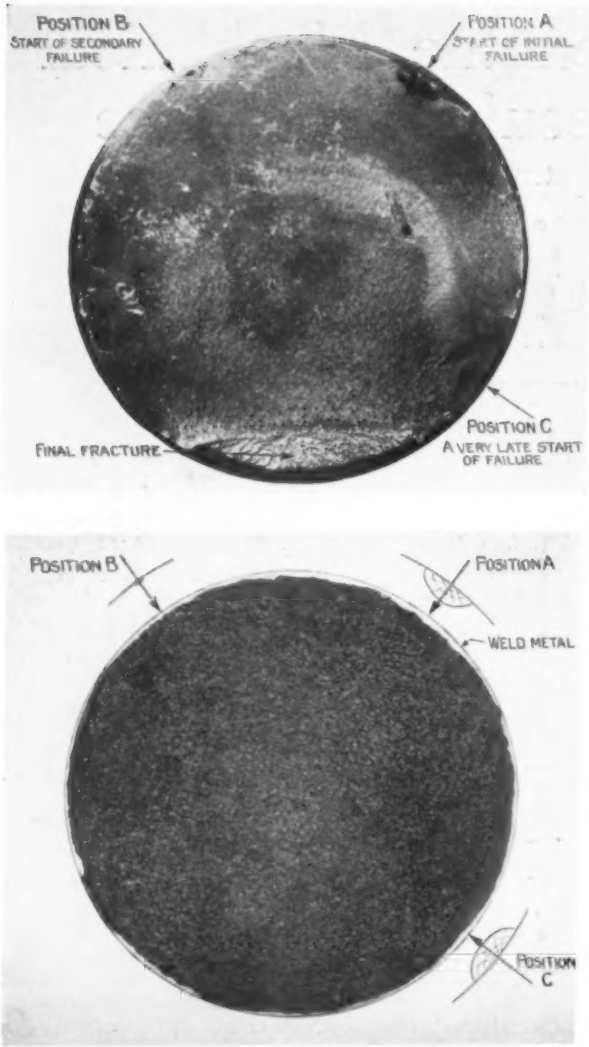


Fig. 31.—Shows one of the surfaces of fracture of the piston rod and, below, a sulphur print taken as close to the fracture as possible.

not at first sight appear to be abnormal. Fig. 32, however, shows a longitudinal section, the surface of the shaft being at the top; the section cuts through the metal at position B and, at the right hand side, extends right up to the surface of fracture. Though, at the left, the weld metal is not particularly thick, it is obvious that the depth suddenly increases, and at the section of fracture the depth is every bit as great as the amount previously shown for positions A and C.

Another type of failure of welded parts arises from concentration stress. An example of this is shown in Fig. 33. Six fan blades had been welded by small fillets to the shaft of a motor. After twelve months the shaft fractured in the manner shown, cracks developing from underneath each of these harmless-looking blades. Another example is shown in Fig. 34. In this case a flange having given trouble, had been welded round the fillet, and at the same time had nominally been reinforced with four stiffening ribs attached by fillet welds; cracks started at the points marked with an arrow. The similarity of the method of fixing these ribs and the fan blades just shown is to be observed. Two months after the repair the shaft broke in the manner depicted, Fig. 35 showing one of the surfaces of fracture.

Fig. 36 explains how the trouble comes about. In each instance the presence of the blades (or the ribs) causes an increase in stiffness of the underlying portion of the shaft. Such increased stiffness can be obtained only at the expense of concentration of stress at the junction of the shaft with the reinforcing elements, and, with a welded-on element, the position becomes exceedingly aggravated, since the whole of the lines of stress, arising from any bending of the unstiffened portion of the shaft, has to be transmitted to the blades through the comparatively narrow cross-section of the fillet welds. I have attempted to make this clear by marking in the hypothetical lines of stress in the two sketches at the left, the lines marked in

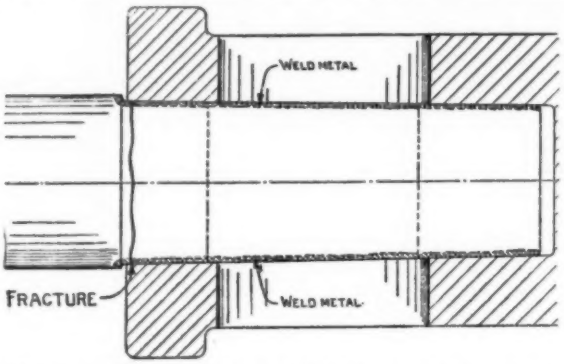


Fig. 30.—A piston rod that failed showing the position of the fracture.

at the right denoting the progression of the cracks. The cause of such failures is therefore fatigue, and it is to be realised that, owing to penetration of the weld metal, the most highly stressed part cannot lie in unaffected parent metal.

With this explanation I will show a much more important example of the same type of failure. It refers to a crank-shaft, over 18 in. in diameter. Trouble had been experienced, owing to the working loose of the keys used for securing the flywheel. The misguided engineer with mistaken zeal had carried out an execrable repair. He had welded the ends of the keys to the shaft by means of fillets, deposited in line with the sides of the flats for the keys, in the manner shown by Fig. 37. Cracks broke out at various points along the periphery of the shaft, all these lying approximately in line with the end of the flywheel boss, at which there was a slight reduction in section.

The cracks are shown in Fig. 38, which illustrates the two halves of the damaged cross section, after the shaft had been broken open under the tup. The coarse arrows show the position of the corners of the flats. It is clearly to be seen that the cracks, as before, had each started

Fig. 32.—A longitudinal section of the surface of the shaft showing the thickness of the weld metal.

underneath the longitudinal fillet welds. Though the welding introduced other factors, it led to a concentration of stress at the fillet welds.

Corrosion Fatigue

Another type of stress causing failure is corrosion fatigue, and Fig. 39 illustrates cracks from this cause; these had penetrated deep into an impeller shaft of a pump by which brine for a refrigerating plant was circulated. The shaft, which was of mild steel, broke after only 13,000 hours' service, and the previous shaft broke after only 9,000 hours.

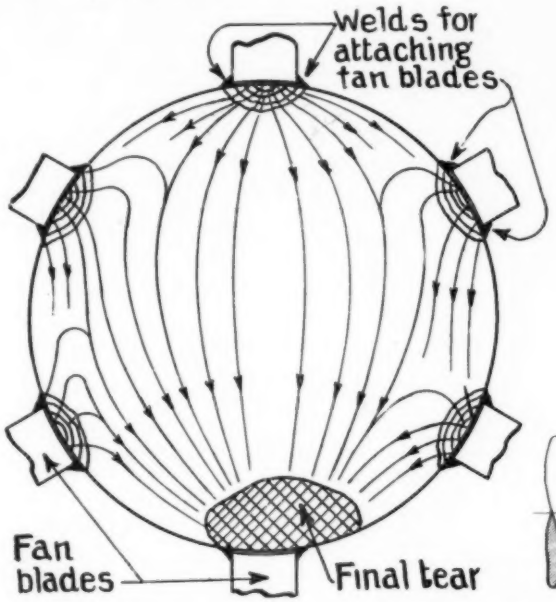


Fig. 33.—Fracture of motor shaft carrying fan blades.

Torsional Vibration

Torsional vibration of crankshafts, since it leads to augmented stresses, comes within the bounds of my subject. Though the primary cause of such failures is incorrect design or operation, the use of metals with good damping properties is desirable in preventing the development of high stresses, and for this purpose it is well known that a normalised mild steel is superior to a heat-treated alloy steel. Sometimes one meets with cases of failure of this type that do not give marked evidence of the cause; on the other hand instances have been experienced when it has been claimed that torsional vibration has been the cause of the trouble, but when it has been possible to prove, from examination of the fractured surfaces, that the reverse has been the case. I will not deal with the theoretical side, but will merely exemplify a few well-marked features.

Failure usually takes the form of multiple cracking, especially at fillets, such cracks commonly lying on complementary principal planes of shear. On several occasions the failure has been due to some ill-advised alteration to the speed or arrangement of the engine, on the part of the owner. An example, showing cracks on complementary planes at a journal, is shown in

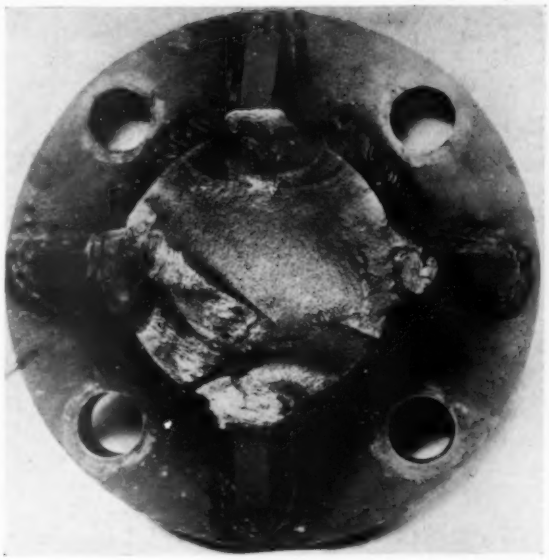


Fig. 35.—Surfaces of fracture of example shown in Fig. 34.

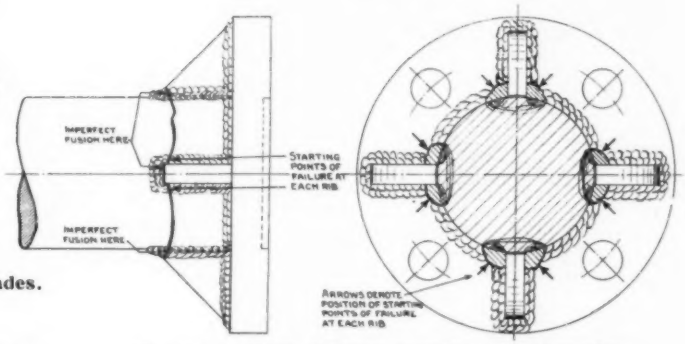

IMPERFECT FUSION HERE
STARTING POINTS OF FAILURE AT EACH RIB
IMPERFECT FUSION HERE
ARROWS DENOTE POSITION OF STARTING POINTS OF FAILURE AT EACH RIB

Fig. 34.—Failure of flange carrying stiffening ribs.

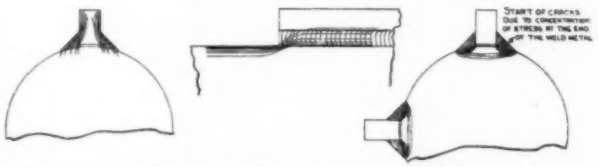


Fig. 36.—Explanation of the cause of the trouble showing the concentration of stress at the junction of the shaft with the reinforcing elements.

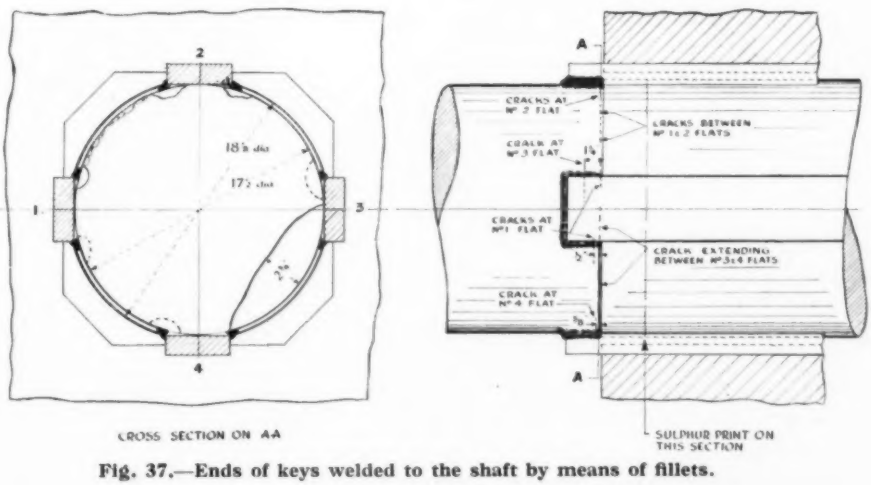


Fig. 37.—Ends of keys welded to the shaft by means of fillets.

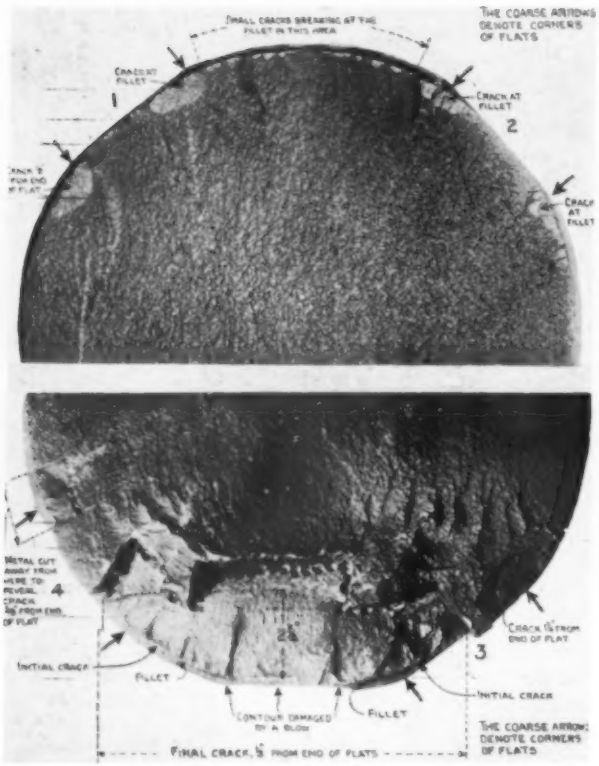


Fig. 38.—Showing the damaged cross section of the shaft illustrated in Fig. 38.

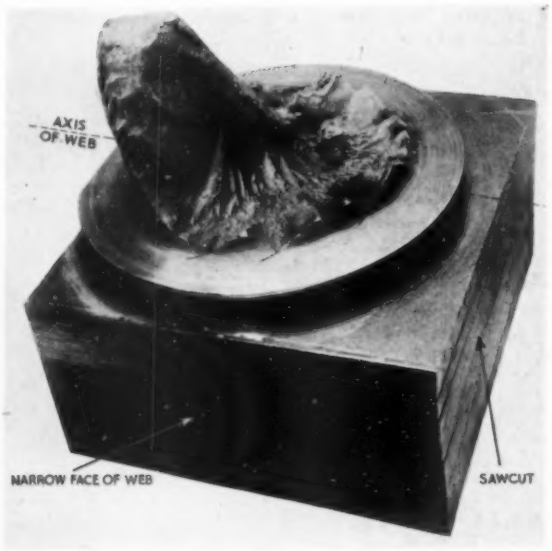


Fig. 41.—Fracture caused by torsional vibration.

Fig. 39.—Cracks caused by corrosion fatigue.

Fig. 40. The natural frequency had been reduced owing to the addition of a heavy C.I. pulley on the crankshaft, and single-nodal vibration of the 7th order had been set up. In the example (Fig. 41), the owners had run the engine above its rated speed, to increase the output. Vibration of the 8th order had been set up.

Longitudinal Tests

Space will not allow me to deal adequately with transverse failures. I will, however, merely emphasise the folly of relying on the properties of material obtained from the usual longitudinal tests, if the greatest stress of service is transverse. Thus the transverse properties of material used for such parts as gear teeth, splines or spline shafts, keyways, and crankwebs are clearly of all importance,

Fig. 40.—Cracks on complementary planes at a journal.

Fig. 42.—Longitudinal cracks in a spline shaft.

and moreover it should be borne in mind that such parts are subjected to considerable concentration of stress. One of many recent failures of spline shafts is shown in Fig. 42. In all these instances longitudinal cracks were first set up at both bottom corners of the splines, finally resulting in transverse failure. For such parts it is certainly necessary to ensure that the transverse resistance to the initiation of a crack at a discontinuity is not unduly low. On making a test, consideration should always be paid to whether the grain of the material lies perpendicular or parallel to the notches of the Izod specimen, and the position of the notch of most importance is that which propagates a crack in the direction that it would propagate in service, be this radial or tangential. The results from notches lying in different planes should not be averaged.

Fig. 43 shows the end of a shaft in which a longitudinal crack developed from a bottom corner of the keyway, while Fig. 44 shows how the crack developed tangentially, resulting in the separation of the outer shell of metal from the body of the shaft.

Failure from Induced Brittleness

The last type of failure to which I shall briefly allude is the failure of certain wrought irons and low-grade mild steels resulting from induced brittleness. The prime cause of the failures is a metallurgical change in the metal, which is outside the scope of this paper. As, however, the mechanical cause of the failure is induced brittleness, of which the visible metallurgical change may be looked upon as an indication, the subject would seem to be legitimate for mention. I refer to a form of precipitation within the metal, which often leads to the presence of well-marked needles. On several occasions when certain qualities of wrought iron have failed, these needles have been present, and the ductility of the material has been lowered. In every instance the material was worked at an elevated temperature, and experiments show that the needles can be produced by exposure for six months at 190° C. The needles are unaffected by a short heat treatment at 300° C., but are eliminated at 400° C. The trouble has often been found in such parts as boiler plates, steam or smoke tubes, and in bolts, nuts, and studs attached to steam fittings. In wrought iron, the needles are often confined to certain piles, and experiments I have made show that certain grades of wrought iron are more susceptible than others. The needles in a wrought-iron

Fig. 43.—Longitudinal crack in a shaft developed from a keyway.

Fig. 44.—The crack shown in Fig. 43 developed tangentially and as shown separated the outer shell of metal from the body of the shaft.

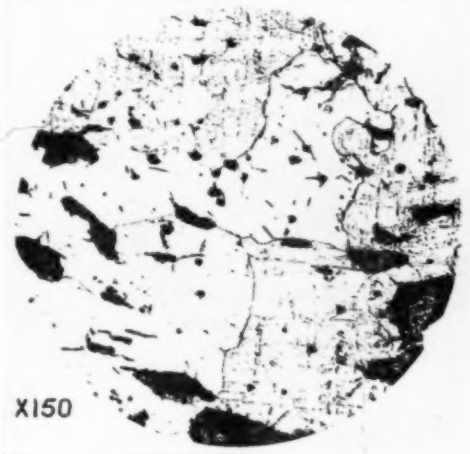


Fig. 45.—Change in structure of W.I. boiler plate causing failure.

Fig. 46.—Similar condition set up in W.I. studs. × 750

Fig. 47.—Structure of embrittled mild steel nuts. × 500

Fig. 48.—Structure of embrittled mild steel studs. × 500

boiler plate, are shown in Fig. 45, while Fig. 46 shows the needles in one of many broken wrought iron studs, affixing a H.P. cylinder cover.

Some results of tests on the studs are given in the accompanying Table. It is to be seen that the normalising treatment caused a lowering of the yield point, a considerable increase in the reduction in area, and a vast improvement in the Izod value. In addition it removed the needles.

Needles in embrittled mild-steel nuts at the joints of pipe flanges are shown in Fig. 47. The whole of the bolts and nuts in the installation had to be renewed. On a fairly severe bend test, transverse specimens suddenly broke through their full section, when the angle of bend was respectively 5°, 45° and 53°; for a sample annealed at 600° C. the angle improved to 96° before the setting up of surface cracks, without their extension. A further example is shown in Fig. 48. In this instance, the needles are shown in the mild-steel studs of a stop valve. Threaded portions of the studs were each bent in an exactly similar manner in a special machine. For samples in the brittle condition, cracks appeared when the angle of bend reached 15°; after annealing treatment at 650° C., the angle of bend was raised to 82°.

Test.	Description.	Test Result	
		As Received.	Normalised.
Tensile	Stud 1	Y. 20·8 t/sq. in. U. 25·1 ,, E. 18% R. 32% Fibrous.	Y. 15·1 t/sq. in. U. 23·45 ,, E. 39% R. 43% Fibrous.
Izod	Stud 2 Notch A	*12·3 ft. lb.	—
	Stud 2 Notch B	4·0 ft. lb.	—
	Stud 3 Notch A	1·75 ft. lb.	54·5 ft. lb.
	Stud 3 Notch B	3·3 ft. lb. Coarse crystalline.	62·0 ft. lb. Almost completely fibrous

* Crystalline, fibrous at middle.

Surface Refinement

THE production of superfine finishes is a refining process following commercial grinding, and is necessary for a variety of reasons, prominent among which are reduction of wear, interchangeability and ease of assembly of parts. The refining process must include removal of surface roughness such as is produced by the grains of the grinding-wheel and which vary according to the grit size used, the bonding and the various means of truing the wheel; and the removal of surface irregularities caused by the actual method or machine itself, these including feed marks, chatter, and undulations. It is evident that the refining process should not merely duplicate the action which caused the errors. Lapping and honing operations are based on principles quite different to those of grinding. The subject has been considered by H. S. Indge,* in which he discusses lapping, honing, superfine grinding, and crankshaft and camshaft finishing.

True lapping is a method of removing metal in small amounts to obtain trueness of form and refinement of the surface simultaneously, and is always performed by the use of abrasive used with laps which, in themselves, have no abrading or cutting action. The comparatively slow rate of stock removal makes it possible to control size accurately, and, due to the nature of the abrading action, little or no heat is generated, and no glazing of the surface takes place. An abrasive for lapping, whether natural or manufactured, should possess the quality of breaking down, becoming finer as the operation proceeds; whether used for hand or mechanical lapping. Included in the group of natural abrasives are iron, corundum, rouge, chromium oxide, tin oxide, quartz, and diamond dust; the most commonly used manufactured abrasives are aluminous oxide and silicon carbide, whilst boron carbide and unfused alumina are also used.

The original hone was natural stone of a fine soft grade, but this method of refining metal surfaces now uses a bonded abrasive as the cutting medium, the absence of loose abrasive and comparative cleanliness of the operation being cited as advantages. Cylinder bore honing is perhaps the most common example, and whatever types of honing head are used all work on the same principle of rotation and reciprocation at low speeds. The need for extreme care in maintaining the truth of abrasive wheels or laps is readily apparent, and this can be attained by the passage of a diamond simultaneously across the face of two wheels running at moderately low speeds and in opposite directions. Wheels of silicon carbide, in special grain of fine sizes, with vitrified bond and paraffin or other light oil as the coolant, are considered to be satisfactory for flat honing.

Superfine grinding is accomplished by the use of one or more grinding wheels finer than those used for commercial grinding, the basic principle being that of successively grinding with fine wheels, each grind removing less than the depth of grain cut made at the preceding operation. A series of fine circumferential lines will, however, be left, even though the apparent degree of polish is a very high one. There is thus a major difference between the superground surface and that produced by lapping and honing, the latter having a cross hatch finish.

The disadvantages associated with the use of split cast-iron laps and inserted abrasive sticks has led to the adoption of coated abrasive cloth and paper for finishing crankshafts and camshafts, employing the same principles of rotation and reciprocation. For finishing camshafts, a machine has been developed in which a duplicate camshaft rotates in unison with the work and controls the movement of a group of individual slide members. In addition to reciprocating the work, a high-speed reciprocating movement is given to the group of slide members carrying the coated abrasive cloth elements.

Whatever process be employed, the surface finish is built up by the use of finer abrasives for each succeeding operation, and it is considered that lapping and honing operations allow production of refined surfaces at high production rates and moderate costs. There can be no doubt that the accuracy of physical dimensions in modern engineering is dependent upon a refined surface, fine limits demanding fine surfaces.

* "Refinement of Ground Surfaces." *Mech. Eng.*, 60–11–807–812.

Soviet Iron and Steel Production

INTERESTING figures relating to the growth of iron and steel production in U.S.S.R. show that in 1913 Russia produced 4,200,000 tons of pig iron, 4,200,000 tons of ingots and steel castings, and 3,700,000 tons of rolled steel. In 1936 production had increased to 14,400,000 tons of pig iron, 16,400,000 tons of steel, and 12,500,000 tons of rolled steel; while during the current year production is expected to reach 16,300,000, 20,300,000, and 15,100,000 tons respectively. This development has been achieved by the construction of large iron and steel plants, and the reconstruction of old ones. The new plants built include those at Magnitogorsk, in the Chelyabinsk Province; at Stalinsk in the Novosibirsk Province; at Nizhny Tagil in the Sverdlovsk Province; at Krivoy Rog in Zaporozhe; at Mariupol in the Ukraine; at Lipetsk in the Voronezh Province, and the metallurgical works at Tula.

Refractories and the Electric Furnace, with Particular Reference to the Roof

By Kilowatt

Attention is directed to the need for research on electric furnace linings, several aspects of the subject are discussed, particularly the roof, which is a frequent source of trouble. Various types of refractory bricks are considered and roof designs for arc furnaces are discussed.

UNDENIABLY, the modern electric furnace is a work of art. No pains appear to have been spared by the metallurgist and mechanical engineer alike in endeavours to make such a furnace as efficient and with as high a power factor as possible. While considerable research has been expended on the mechanical and electrical sides of electric furnace practice, however, too little care and attention appears to have been given to the all-important question of the furnace refractory lining.

Little will be said here regarding the refractories for the electric furnace body, for depending on the quality of steel being produced will inevitably decide whether an acid or basic lining is indicated. If the former type of steel a silica brick lining is used invariably, and throughout the body, although a slight modification—and cheapening—is possible by using a good grade of firebrick above the slag line and extending to the skewbacks. If the furnace is working on basic steel, then obviously a corresponding basic brick lining is necessary. Magnesite bricks of MgO content about 85% are most commonly used for basic linings, but due to magnesite offering rather poor resistance to spalling, an improved type of brick in the nature of a chrome-magnesite is rapidly replacing the "straight" magnesite for the furnace body. The main advantages derived from these chrome-magnesite bricks (there are now several excellent brands of proved success on the market) as against the use of ordinary magnesite, are, briefly, their higher refractoriness-under-load and a far superior spalling index.

It would not be conjecture to state that it is only a matter of time before magnesite bricks as we now know them are eliminated completely by these improved chrome-magnesite refractories. In this article, however, it is intended to deal principally with the furnace roof, which usually proves to be the greatest source of trouble and maintenance expense. Whether a furnace is working on either acid or basic steels, the same class of roof is usually employed. Thus, turning to the actual furnace roof, firebrick material will be considered first.

Firebrick

For firebrick to be used at all successfully in the furnace roof, the brick must be of the highest grade possible and possess an alumina content in the region of 42–44%. Firebrick has definite limitations, for it begins to "soften" at comparatively low temperatures, although following this initial softening, firebrick is capable of maintaining its stability over a wide temperature range. It is doubtful, even in the most up-to-date of firebrick works, whether firebrick refractories are fired in kilns to temperatures above 1,450°–1,500° C.

For normal furnace purposes such a burning temperature is adequate, but for high alumina firebricks to prove at all successful in an electric furnace roof, a higher degree of burning during manufacture is not only desirable but essential. The exacting conditions peculiar to the modern arc furnace are known to heat the roof to temperatures well in excess of 1,500° C., so it is clear to see that the firebrick, apart from chemical attack, will be subject to still further "firing" as it were, which will thus produce additional shrinkage in the bricks. This extra shrinkage will tend to weaken the roof and, maybe, to such an extent as to endanger complete collapse.

Firebrick for roof purposes is definitely not to be recommended, although one is well aware that 42–44% (and less) Al_2O_3 bricks enjoy good popularity in certain quarters. No doubt this popularity is due mainly to firebrick being a comparatively cheap type of roof lining, initially, compared with other refractories.

Silica

Due perhaps to its better load-bearing properties at elevated temperatures and its higher refractoriness, silica has come to be regarded as the standard type of brick to be adopted in electric furnace roof linings. As in the case of magnesite, the chief weakness of silica as a refractory is its marked tendency to spall, or its inability to withstand violent temperature fluctuations.

Is it possible to improve to any appreciable extent the resistance of a silica brick to spalling? Recent investigations into this problem with which the writer has been connected, have shown conclusively that a "soft-fired" silica brick is able to resist spalling far better than the customary "hard-fired" brick. The physical structure of the former brick appears to be better fitted to withstand the stresses and strains peculiar to spalling. Hence it is a strong possibility that an electric furnace roof lining could be improved so as to give longer life by using less "hard-fired" bricks, which are, as has been found, less prone to spall.

A silica refractory of specific gravity exceeding 2·35 appears to be looked upon with disfavour. The Institute of Gas Engineers' Specification states that a straight silica brick must not possess a specific gravity exceeding 2·35, and this specification has apparently grown to be recognised as applying to most other industries apart from the gas industry. It is argued that a powder density in excess of this figure is bound to show that the silica brick is underfired and thus certain to give rise to excessive expansion, at melting temperatures, in the furnace roof. Such a theory is not necessarily correct, particularly in view of the fact that there are already several grades of silica bricks with specific gravities in the region of 2·38 to 2·40 which are being used successfully for roof linings and with but normal expansion. Frankly, the writer contends that too much stress and importance is placed on the specific gravity property of a silica refractory. Rather ought this factor to be replaced by, or at least augmented by, a factor based on *permeability*. A standardised method of measuring the permeability of a silica brick—or any other grade of refractory for that matter—could prove more valuable in assessing the quality of the brick than either the specific gravity or porosity values. A less permeable silica brick in the electric furnace roof would be better capable of counteracting the erosive action of the furnace gases and also offer added resistance to the penetration of iron oxide, resulting in an increased life for the roof. Briefly, if silica material is to continue to hold pride of place for roof linings, then it would appear imperative that research should proceed on the lines of producing a brick more resistant both to spalling and permeability.

Sillimanite

In turning to the application of sillimanite material to an electric furnace roof, one enters into the field of what might be called, "super-refractories." One is apt to look upon sillimanite as being a refractory reserved almost

exclusively for glass tank furnaces, but there are several other applications in existence for sillimanite, one of these being found in the electric furnace roof.

Sillimanite is a pleasing white-looking refractory, and any such brick of repute will show an alumina content of at least 60% and give a refractoriness-under-load test of approximately 1,710°–1,720° C. This high under-load figure is but one of the several features which commends sillimanite for use in the type of furnace roof under discussion. A figure of 1,710°–1,720° C. is obviously over and above the roof temperature likely to be encountered in the severest of electric furnaces, so that there will be little likelihood of the roof " running," as is the case with firebrick and silica materials.

Secondly, the resistance which sillimanite offers to spalling is phenomenal, and this factor is responsible for making this type of refractory so admirable for roof lining purposes. A common spalling test as applied to refractory materials generally is as follows. The brick to be tested is taken and heated in a muffle furnace to roughly 1,200° C., and then plunged into a container of cold water and cooled completely. The brick is then removed from the water and replaced *immediately* in the hot furnace and again heated up. As soon as the conditions in the muffle are constant, the chilling operation is repeated. This procedure of heating and sudden cooling is continued until the refractory disintegrates. It is possible with a good grade of sillimanite brick to carry out the above spalling test for as many as thirty times (and often more) without any perceptible disruption of the brick. When it is stated that a firebrick or silica brick does not as a general rule withstand the stringent spalling test for more than five to twelve operations, then the ability of sillimanite to resist spalling will be more readily appreciated. An arc furnace roof with which the writer has had dealing recently, failed miserably on several occasions when lined with a high-class silica brick. The management was persuaded finally to incorporate sillimanite in the roof, and the success attending this change-over was remarkable. The melting shop manager was literally astounded at the spalling resistance of the sillimanite roof. The furnace could be started up—from cold—say, on a Monday morning and be ready for tapping within a few hours. In addition, cooling down from melting temperatures was possible just as quickly and in each case without the slightest deleterious effect on the sillimanite furnace roof. Such rapid heating and cooling on firebrick and silica materials used previously had proved fatal to the brickwork within the course of comparatively few melts.

The discussion on sillimanite cannot well be left without reference being made to its expansion. At temperatures as high as 1,600° C. sillimanite keeps its volume stability to a marked degree, which fact contributes further to its success as an electric furnace roof refractory. The actual expansion of sillimanite is but slight, and absolutely uniform during any temperature range, which thus eliminates any possibilities of critical temperatures. Roughly speaking, the expansion can be taken as being about 0·04% or so per 100° C. rise in temperature. Negligible allowance need be made for expansion in a sillimanite roof, whereas appreciable wooden joints are introduced into a silica brick roof to compensate for the expansion, the wood, of course, burning away as the temperature of the furnace is raised and the major part of the expansion has taken effect at 575° C. The word " expansion " spells fear in the minds of numerous furnace operators, but no uneasiness on this score need be entertained when the arc furnace roof is built of sillimanite.

Not only from a theoretical consideration, but also from actual, practical experience, one is bound to conclude that of all the several types of refractories at present available, sillimanite constitutes the *ideal* brick for use in arc furnace roofs.

Chrome-Magnesite

Brief reference was made at the commencement of this article to the use of chrome-magnesite bricks in the electric furnace body, and there are those who are now advocating strongly the extension of the use of such bricks to the roof also. Several instances could be mentioned where roof linings in chrome-magnesite are at present in operation, but at the time of writing no accurate or sufficient information is available as to the success likely to be achieved.

Fundamentally, a roof lining in chrome-magnesite should give entirely satisfactory results, seeing that a brick of this nature has been specially compounded to replace magnesite and to show increased spalling resistance and also to possess higher refractoriness-under-load. The weakness of a chrome-magnesite brick, however, is its tendency to absorb iron oxide and form a layer of magnetite, Fe_3O_4, a matter of about half an inch inside the brick from the face of absorption. The layer of magnetite grows to such an extent as to disrupt finally the face of the brick. Hugill made lucid reference to this magnetite growth inside chrome-magnesite bricks when lecturing in Sheffield recently to the Refractories Association of Great Britain. In order to combat this ferrosoferric oxide inclusion phenomenon, one is led back to the question of permeability, as mentioned earlier under the silica section. If the permeability of the chrome-magnesite brick were lowered, it is more than reasonable to expect that the penetration of iron oxide would be reduced correspondingly. No doubt research will proceed on these lines, and if and when failure of a chrome-magnesite brick due to magnetite attack has been eliminated, one can look forward to the increased use of chrome-magnesite linings for arc furnace roofs.

Roof Design

Perhaps a word here on arc furnace roof design would not be out of place. The present position is one which calls for immediate investigation and closer co-operation between arc furnace builder and refractory manufacturer. The former is far too prone to ignore the latter, and thus endeavours to design the roof brickwork to his own taste and whims, and consequently it is not infrequent to find that the refractory manufacturer is faced with a difficult proposition in making the refractories to fit the roof in question. Some of the designs of the roof brickwork are extremely intricate. True it is that one or two arc furnace builders adopt fairly simple lay-outs in their roofs, such as building up the entire roof—apart from the skewbacks—with squares, side and end arches and crowns, and yet still imparting to the roof a strong, keyed structure, but, nevertheless, the fact remains that wider and more intimate co-operation is badly needed. Such co-operation would obviously benefit both the furnace builder and the brickmaker.

The writer knows of one instance where two identical 3-ton arc furnaces belonging to the same firm are fitted with dissimilar and complicated designs of brickwork in the roofs. Separate sets of expensive moulds have to be kept by the brickmaker for manufacturing purposes, yet it does not appear to have entered anyone's head to perfect and standardise one simpler design of roof lining for both furnaces. The existing situation borders on the farcical, to say the least. Nor is the example cited an isolated instance of this lack of co-operation. It is not, for such a state of affairs is all too general in the arc furnace world.

There is much awaiting to be done on this aspect of roof design, and it may be that the future will witness genuine co-operation, for which a plea is now made, between the respective parties concerned.

Röntgen Apparatus of 500,000 volts

THE Moscow works manufacturing Röntgen apparatus has produced four high-tension X-ray machines of 500,000 volts. One of these will be used for the treatment of cancer at the Moscow Institute of Röntgenology and Radiology. It is also intended to use the new apparatus to X-ray heavy metals for the purpose of detecting defects in castings and weldings, and one of the machines will be installed at a works manufacturing transport equipment.

The Tin Industry in 1938

A Survey of Progress in the Development and Applications of Tin

Although the consumption of tin has declined during 1938, great activity has been devoted to the development of increased facilities for the production of tinplate, while investigations of considerable metallurgical significance have added to knowledge and practical applications in many fields. Some of these developments and investigations are reviewed.

Consumption

IN common with most other metals, the world consumption of tin declined sharply during the first nine months of the past year, and for the whole year is not likely to exceed 150,000 tons, as compared with 200,000 tons in 1937. It should be remembered, however, that 1937 was a record, beating the previous highest year, 1929, by 10%, and probably some part of purchases of tin were for stocks which have been used only this year. The greatest decrease was in the U.S.A. during the period January to September, consumption being 42% less than during the corresponding period in 1937. Decreases of 29% in the case of the United Kingdom and 28% in the U.S.S.R. were to some extent offset by increased purchases by Germany, Italy and Japan of 14, 36, and 22% respectively. Sweden consumed 900 tons more, enabling it to record a 64% increase ; France's consumption remained unchanged.

As would be expected, the same trends are reflected in the figures for tinplate production, the world's average monthly output being 355,000 tons in 1937, but only about 250,000 tons in 1938, the most serious decline being in British and American outputs during the early summer, while French and German outputs remained steady.

Continuous Process for Tinplate

The new continuous-strip rolling mills at Ebbw Vale were completed in 1938, and in the early part of 1939 it is expected that the tinning plant for manufacturing a part of the output into tinplates will be ready for operation. To meet this competition it is possible that reversing mills for producing continuous strip will be installed in some of the older established factories. Britain's future capacity for tinplate production should therefore compare more favourably with the United States, where there are already several continuous-strip mills in operation.

Continuous tinning of relatively narrow steel strip up to nine or ten inches in width can be carried out by the hot-dipping process, but is not yet practicable for greater widths, such as 2 ft. 6 in. Attention is therefore being given to electro-deposition, and at least one plant in America has produced electro-deposited tinned strip, which is being tried out for tops and bottoms of dry-packaging containers and other large installations are contemplated.

Measurement of Thickness of Tin Coatings on Tinplates

The year has produced a number of interesting results in the field of research. Two methods of measuring the thickness of tin coatings on steel, such as tinplate, were announced by the International Tin Research and Development Council. One method measures the intensity of the pull required to detach a permanent magnet from a point on the surface of tinned steel, the force decreasing in proportion to the thickness of the intervening non-magnetic tin coating. The other method employs an electromagnetic principle ; a miniature transformer with an open core is placed on the tinned steel sheet, so that the magnetic circuit is completed through the sheet. The gap due to the tin coating causes a variation in the intensity of the flux produced in a secondary winding by a given current through the primary transformer windings. Both these methods have the advantage that the test is non-destructive and instantaneous.

The electromagnetic method lends itself to routine factory application, but so far it has not been possible completely to eliminate the influence of the variations in magnetic permeability of the steel basis sheet. Progress has already been made in this direction, and the possibility of complete success is envisaged.

By the magnetic method, investigation into the thickness of the coating can be carried out upon what are, for practical purposes, mere points. By its use the presence of ridges in the tin coating of tinplates has been confirmed, and it has been established that the thickness of the coating between the ridges may fall to 60% at those places.

Flux Inclusions under Tin Coatings

Some valuable information has been obtained about flux inclusions under tin coatings on steel. It is sometimes found that tinplates are " sweating " with tiny droplets of liquid, and if lacquered give poor results, due to bad adhesion. Tinplates exhibiting this defect were detinned with pure dry mercury, leaving only the tin-iron compound. Droplets of liquid formed after exposure to moist air and were shown to contain zinc chloride. The sites of these droplets were shown to be the fissures produced by intercrystalline corrosion during pickling. By suitably regulating the pickling the intercrystalline corrosion can be completely prevented, and, in consequence, the amount of flux inclusions can be considerably lessened.

High-Tin Bronzes

Further work has taken place in connection with the high-tin bronzes which came into prominence last year. Extraordinary malleability and corrosion resistance are characteristic of bronzes containing 10 to 12% of tin when the founding and casting are carried out in such a way that the metal is completely degasified. Under these conditions the tin is present entirely in solid solution in the copper, thereby differing from bronzes cast in the normal say, which contain crystals of copper-tin compound distributed in them. In the solid solution bronzes, therefore, the whole of the tin develops its corrosion-resisting and strength-giving properties, and the result is virtually a new alloy. The ultimate strength and ductility of these bronzes is substantially improved, and their hot- or cold-working is greatly simplified.

Among the many uses for which these new bronzes are outstandingly suitable may be mentioned condenser tubes. In tests of a type which have been confirmed by years of practical experience, these tubes have shown a corrosion and erosion resistance equal or superior to any other alloy tubes now available.

" Stannising "

" Stannising " is the name given to a new method of coating metals with tin by decomposition of a volatile tin salt. The process involves cleaning the articles in a solvent or in soap and water, and heating them around 500° C. in an atmosphere of hydrogen carrying volatilised stannous chloride. The tin is undoubtedly deposited in the pure condition, but at the elevated temperatures used is speedily alloyed with the basis metal. For example, on copper at low temperatures a tin-copper alloy is formed, but if the temperature is raised or the soaking time lengthened, the copper content of the coating rises.

Possible fields for stannising appear to be in coating

those products which would be benefited by a tin-alloy coating rather than one of pure tin. Very thin, even coatings are possible by vapour coating even over rough, threaded, and irregular surfaces. It should be possible, therefore, to stannise as a final operation, after machining slightly to undersize. Because of the penetrative power of vapour, recessed articles and the insides of tubes and similar objects can be coated with tin by this method. Since many of the tin alloys, notably with copper, are extremely hard, wear resistance far in excess of that obtainable with pure tin appears possible. A bright, hard, mirror-like surface, such as speculum metal, Cu_4Sn, can be produced. Further, as the intermetallic compounds are formed by diffusion, it is possible to produce a homogeneous surface of one constituent only instead of a more complicated cast structure.

Properties of Tin and Tin Alloys

Researches on the mechanical properties of specimens consisting of a single crystal of tin or of a controlled number of crystals and boundaries have led to conclusions of fundamental metallurgical significance. Another branch of fundamental investigation undertaken is upon the thermal phenomena occurring in tin during its passage into the superconductive state.

In the general field of tin-base alloys, there has been a systematic investigation of the effects of small quantities of other metals on tin when added one at a time. In this way the influence of antimony, copper, cadmium, germanium, beryllium, tellurium, nickel, manganese, iron, aluminium, bismuth, and silver is becoming more completely understood. Cadmium and antimony make alloys with tin, which are amenable to heat treatments, whereby the mechanical properties can be modified considerably. Very small amounts of tellurium, 0·05%, have been found to improve the creep strength of tin by more than double, but scarcely affect other properties.

Progress has been made in the constitutional study of the ternary alloys of tin, cadmium, and antimony, some promising alloys possessed of superior mechanical strength having been discovered. Heat-treatment in many cases effects great improvement.

In these investigations the structure and constitution of the new alloys has been determined in all cases, so that mechanical properties, composition, and heat-treatment can be correlated. Creep strength has been shown to be greatly influenced by the grain size of the alloys. This information is likely to be of practical application in solders, bearing metals and pewter, applications in which improved properties are required to meet the ever-increasing demands of new products and new methods of manufacture.

Bearing Metals

Tin-base bearing metals have been the subject of continued study. Failure by cracking is generally considered to be due to fatigue cracking of the bearing metal and work has progressed in a study of the fatigue properties over the range of temperatures met in modern high-speed internal combustion engines—i.e., up to 150° C. Because fatigue tests have to be made over a long period, a classification based on tensile strength is being carried out as a fair correlation between these properties. Information on the fatigue strength of a wide range of alloys from room temperature up to 150° C. has been published. Trials are being made on a number of the more promising of these alloys in machines that have been constructed for the testing of bearings under conditions which impose very severe pulsating loads at controlled oil temperatures, so that direct comparisons can be made of their resistance to cracking.

The creep strength of solders has been studied at temperatures up to 100° C. An investigation into the wiping qualities of "frosty" plumbing solder showed that where the cause of the frostiness was slow cooling of the bars after casting and not the presence of impurity, such as aluminium or zinc, the working qualities were indistinguishable from those of bright bars of the same composition.

Electro-Deposition

Work has been done upon the production of nickel and nickel plus chromium coatings on tinplate in order to establish the conditions that secure satisfactory adhesion and allow of severe deformation during the progress of fabricating into decorative articles. It is recommended that "charcoal" grades of tinplate be used, as the use of this superior quality minimises the risk of rusting at breaks and pores in the plated coatings, the adhesion is better, and a good finish is more easily obtained. For some years past chromium-plated tinplate has been extensively used for pressings of all kinds for the manufacture of trays, boxes, bags, reflectors, and lamps, and miscellaneous metal fittings.

Bronze Plating

Progress has been made in meeting the difficulties of providing a bronze undercoat for nickel and chromium.

Tin Plating

Reference was made earlier to the interest attaching to methods for coating continuous steel strip by electro-deposition. A survey of some of the fundamental problems involved was published recently, on the basis of results obtained in laboratory trials, and special advantages were noted for the acid bath, in which speeds of electro-tinning comparable with those used for the hot-tinning process, appear to be practicable. A laboratory machine for polishing under controlled pressures and speeds was devised and has given useful data on the effects of polishing and scratchbrushing exceedingly thin coatings of the order of 0·0001 in.

Tin Compounds

In the field of tin compounds it is interesting to note that although several competitive opacifiers have been developed the many valuable qualities of tin oxide are receiving greater appreciation; in particular, it is recognised that tin oxide improves the thermal and shock-resisting qualities of enamels and its greater intrinsic opacity facilitates the trend towards thinner enamels. Such facts as these, coupled with its non-toxic properties, ensure that tin oxide will continue to hold a major place among spacifiers.

Thermo-Anthracite from Ural Coal

IT is reported from Zlatoust (Urals) that a special thermic furnace for the production of thermo-anthracite, a new kind of cheap fuel for the melting of pig iron, has been constructed at the Kusinsk iron foundry. The Sverdlovsk Institute of Ferrous Metals has for some time been working on the problem of obtaining thermo-anthracite from the Yegorshino coal deposits in the Urals. Experiments in this connection have produced good results.

The Mineral Production of Canada in 1938

THE production of Canadian mines in 1938 was valued at $440,634,000, being a 4% decrease as compared with 1937, due almost entirely to the decline in base metal prices, a falling-off in sales of some of the more important non-metallic minerals, and curtailed output of structural materials.

Gold output reached a new peak, and the productive yield widened, whilst the production of crude petroleum was more than double that of 1937. The discovery of an extensive new copper ore body at the Waite-Amulet mine in Quebec added to the economic importance of that property; a new line of railway has been completed, serving the mining belt of North-Western Quebec. Copper, lead and zinc have been produced in greater quantities than ever before. Canada's mining industry is now established on a very firm basis, and its success reacts favourably on the whole economic life of the country.

Industrial Management and Production Control

Part IV.—Wage Systems

By F. L. Meyenberg

The wage system employed in any works is of fundamental importance in maintaining a spirit of real co-operation between the management and the men, which has such an influence on the prosperity of a firm. In this article the author discusses the demands of a wage system, and proceeds to consider various systems in operation.

THESE articles are intended to be of *practical* use. Thus we have to put aside all theoretical considerations as far as possible; but one restriction must be made: if we want to apply any method in practical life, we must clearly recognise what is the basic idea that governs it, what are the reasons of its applications, and what is the effect we want to create. In this sense we will approach the problem of wage systems; only then will we be able to penetrate the underwood which has grown up round this problem, nourished by selfishness, profiteering minds, and misunderstanding of social relations, etc.

If this unbiased attitude is generally needed when pondering on any unsolved problem of life, how much more is it necessary to answer the question how men shall be paid for the work they do in an industrial works, or, better still, how wages should be determined to meet the interests of both parties, employer and employee, in a manner as fair as it is possible under the seemingly conflicting interests.

There can be no doubt, however important other working conditions may be in forming the relation of the men to their firm, the wages problem will always be the most significant—and rightly so. If an industrial undertaking has succeeded in building up the wage system in such a manner that a fair compromise has taken place between the demands of the management and the men, and if this system is applied so that the men, consciously or unconsciously, feel this fairness, much, if not all, is gained for real co-operation, so important for the prosperity of the firm.

The Demands on a Wage System

What now are these demands which the management on the one hand and the men on the other hand may righteously put to a wage system? Before we make the attempt to define these demands, it may be useful to point out that we do not speak in this connection about the *absolute* amount of money which has to be paid to the man for a given time or certain work, but about the *relation* of the figures for different work or different men. Later, it will be made clear how the transition from the relative to the absolute figures has to be made with the aid of factors determined mainly by the necessity for maintaining the works in a competitive position.

The management has an interest in the system which is covered by the following:—

A1. The calculation of the wages should be as simple as possible.

A2. The value of a certain work done should be capable of determination beforehand.

A3. The amounts of wages for different jobs should be proportional to the difficulty of work involved.

For the men, it is important that:—

B1. They should easily understand how their earnings are built up.

B2. The fluctuations in their earnings should be tolerable.

B3. Different men with different earnings should have their earnings graduated as far as possible to the difficulty of the jobs and the ability and industry of the men.

This summary, which only gives the main demands, shows that if we, for the moment, disregard the absolute figures, the demands of the management and the men on a wage system are nearly identical. The best known and most-used wage systems are the fixed hourly rate and the piecework rate; all others are more or less built up on one of these two or a combination of both. It will, therefore, be useful to consider separately these two systems, and more in detail.

The Fixed Hourly Rate

This is the oldest, but still very much used form of wages, and I am convinced that the development of modern industry will again bring about preference for this form, after it has been tried as an emergency measure in cases where other "higher" wage systems could not be used. The calculation of the earnings of the man is so simple in this system that it needs no explanation: the time the man is in the works is multiplied by the fixed hourly rate. It will be clear that the demands A1, B1, and B2 are fulfilled perhaps as completely as possible. But as no really direct relation exists between the rate and the work, neither demand A2 nor the nearly identical demand A3 and B3 can be fulfilled.

On the other hand, it has to be considered that the development of the industrial technique is certainly directed towards relieving the worker from manual work and in making him the leader of machinery which does the actual work. As the most highly developed example, consider a modern power station, where the work of the men is almost completely reduced to the observation of measuring instruments and the moving of certain levers and switches. (In order to avoid misunderstanding, it may be expressly pointed out that this has increased rather than lowered the importance of the man's work.) Or consideration may be given to the high-production technique developed, for example, in Henry Ford's factories, where the equipment of the shops, especially the transport system, determines the speed of the work, and therefore rules out any other wage system. In addition, the fixed hourly rate is used in other industries where the nature of the work forbids or makes it impossible to predetermine a certain time for a given job. This is largely the case for repair work, where, too often, during the work itself, unforeseen jobs must be carried out, and the interests of the firm are best served when the men are not unnecessarily hurried in making a thorough and good repair.

In such cases it is generally uneconomical to give the men a special incentive to speed up repair work: the machines which have to be repaired, either after a breakdown or in the form of the periodical overhauling, are usually so valuable that a longer time, and therefore more costly repair, does not count if thereby a real improvement in the state of the machine is reached or the danger of a repeated and perhaps more serious breakdown is avoided. The same applies in the case of work which needs special care or attention, as, for instance, inspection work and the making of tools, jigs, gauges, etc. It would be foolish to endanger the result of work, perhaps many times as costly, by hurrying the inspection and thus saving a small part of its costs. Further, in modern industrial works, the work

of one shop or department is frequently so dependent on that of another that this very fact provides the men with an incentive to repair the machine in question, or to deliver the necessary tool or gauge, etc., as quickly as possible, as they know that their colleagues are waiting for it and will perhaps even experience losses, if undue delay of the necessary repair occurs.

It cannot be denied, however, that our demands A2, A3, and B3 are not fulfilled, and that the nature of the fixed hourly rate system does make it nearly impossible to fulfil them. As these are very important demands, it is only natural that efforts to overcome these difficulties have been made by another wage system. That may be the origin of the piece-rate system.

The Piece-Rate System

A closer connection between the amount of payment and the amount and quality of work done is required, on the one hand, because it seems to be fair, on the other hand, because it is important, sometimes even vital for the management to know beforehand the actual costs of a job. Again, let us remember that we are dealing with the problem from a *practical* point of view. We are well aware that a certain school of thought, the purely socialistic one, declines this connection between wage and work but to treat this problem is outside of the scope of these articles.

This demand that the wage paid and the amount and quality of work done should be proportionate to one another, is perhaps one of the most difficult to fulfil in industrial practice. The most experienced specialists agree that this problem is by no means completely solved or that it can be solved under our present knowledge of human physiology or psychology. But that does not relieve us from the obligation to attempt its solution as far as possible. The difficulties involved in, and the imperfections connected with, applying this idea in practical cases may perhaps best be understood by considering how this problem has been treated in the course of time.

The Original Method of Fixing Piece-work Prices

The foreman of a shop is asked to fix a piece-work rate for a certain job. He " guesses," according to his experience, how long a man will take to do it, perhaps 30 mins., and as this man earns on the average 2s. per hour, he fixes the piece-work price to 1s. The man, of course, contradicts and explains that he needs 50 mins., and after a certain discussion they agree on 40 mins., and the piece-work price is fixed at 1s. 4d. It is from this imperfect method of rate-fixing that this wage system is sometimes termed " accord system."

Our example is certainly crude, and in this form may not occur in practice to-day, but if one goes to the root of the method applied, this kind of guesswork is more prevalent than is imagined, although it is veiled in one way or another, and therefore not so obvious to the critical observer. But why do we condemn this method so sharply ? Experience shows that seldom is pure guessing correct. Either the price obtained is too low and trouble is encountered with the man, who cannot earn the money he believes himself entitled to ; or the price is too high and the man earns more than the foreman expected. The latter protects himself by cutting down the price, one of the most objectionable procedures in the system, because it destroys the confidence of the men in the management, as any breach of promise is bound to do ; or the man, who has learned his lesson by former price-cutting, slows up his work in order to earn just as much, or only a little more, as has been expected. Both parties, management and men, suffer a loss.

Perhaps there are some piece-work prices in the shop which are too high, and some which are too low, in the sense explained above ; it is possible, however, and indeed usual, to draw a veil over the whole procedure by mixing these " good " and " bad " piece-work prices—to use the normal workshop expressions—in such a manner that the mistakes made do not come to light. Even the foreman sometimes favours this proceeding, either because he fears the objections of his superintendent for fixing wrong prices, or because he wants to avoid trouble with the men.

It may perhaps be said that I exaggerate ; the actual conditions in practice being not so bad as described ; but he who has occasion to investigate various industrial works, or to discuss this matter with colleagues in other undertakings, knows very well that though such conditions have perhaps ceased to operate in the factory of any individual reader of these lines, they are, nevertheless, often customary, he may believe, in other works. Certainly, however, it should be clear that such piece-work prices do not fulfil our stipulated demands : they neither give in advance a true picture of what a job will cost, or, better, *should* cost, nor are they really, or at least approximately, proportionate to the amount or quality of the work to be done.

The Modern Method of Fixing Piece-work Prices

In order to avoid the mistakes explained above, it is primarily necessary to entrust with the difficult work of piece-rate fixing a man who can devote to this job more time and thought than the busy foreman can afford. This step is taken frequently, and the " rate-fixer " has made his appearance in industrial works. Unfortunately, it is sometimes believed that that is enough, a belief which is definitely wrong. If this man works according to the old method, no improvement takes place ; very often indeed there is deterioration, as his connection with the shop is not so close as that of the foreman. Much more important is that he should use different methods of rate-fixing, such as estimation based on careful works analysis ; calculation where it is possible—i.e., where the working time is governed by machine and not by hand-work ; work and time studies on equal or similar work in the shops themselves ; comparative and statistical methods by means of tables and graphs ; all are closely adapted to the present working conditions or those that can be expected in the future, when proposed alteration or further development has taken place.

It is not possible here to consider in detail this important work, of which mention has only been made of one point of view ; the reader seeking more enlightenment must be referred to the extensive special literature on this " science," which has been developed during recent years. One point, however, may be mentioned : it is not a " science " in the accepted sense of the word, for there are too many basic facts still insufficiently investigated, and too many empiric values must be used ; but it can be stated that sufficient is known to develop in practice methods which avoid many of the mistakes of the old method of rate-fixing and which give fair figures for the working times of various jobs.

Up till now we have been concerned with the determination of time ; there is a second and not less intricate problem, the transition from time to money which remains to be made.

The Transition from Time to Money

This seems to be so simple, in view of the various agreements with the men's organisations. For nearly all the various positions of the workmen in each trade hourly rates are fixed, and a special clause makes it clear that if the work is carried out against a piece-work price, the men are entitled to 25, 30, or 33%, etc., in excess of the earnings on a fixed hourly basis. In such cases it is only necessary to increase accordingly, and the desired money factor is found with which the working time must be multiplied to obtain the right piece-work price. This is the usual way and, I believe, the best way under present conditions.

I should like to point out, however, that injustice and unfairness can easily creep in, and for the time being perhaps it cannot be avoided ; it may be desirable, therefore, to give this point more detailed consideration. The

social conditions between employers and employees have been so developed that the agreements previously mentioned are considered from the one side as a maximum and from the other as a minimum of the demands of payment ; and they have thereby obtained an inflexibility which makes it nearly impossible to take into account the variations of difficulty between jobs belonging to the same heading of the agreement. Various methods of avoiding this difficulty have been applied in practice which cannot be discussed here in detail, but they have been applied sporadically, and a more systematic treatment of this problem seems to be worth while. Certainly it will take much time and work before the basic facts are clear and before their practical application will be possible ; these short hints, therefore, may only be considered as attempts to draw attention to a problem which is often completely overlooked. That seems the more important, as these remarks also apply to the fixed hourly rate system.

No " Price-Cutting " in Future

One point, however, must be emphasised before leaving the piece-work wage system. After a piece-work price is fixed in the manner previously explained, it should be changed only when an actual error has been made, and then only after it has been openly discussed with the men and agreement is obtained, or when a clear change of the working conditions has taken place and the basic factors of the fixed price have been altered. The bad method of " price-cutting " must disappear to preserve good relations. Only when this rule is strictly followed and the men have the confidence that they will be treated fairly, is it possible to prevent that unpleasant behaviour of the men, which production engineers know only too well as slowing down working capacity, a kind of passive resistance, which men use as a weapon against unfair treatment. In such a case the men no longer work as they *can*, but as they are *expected* to work by the rate-fixer, and an equalisation of the hourly earnings takes place, which nearly wipes out the differences between the skilful, the average, and the weak worker, with the result that the level of piece-work prices is lowered more and more to the capacity of the last one. I have known cases where this phenomenon has lowered the output of the works 20% and more, under the possible output, thus endangering the very economy of the whole concern.

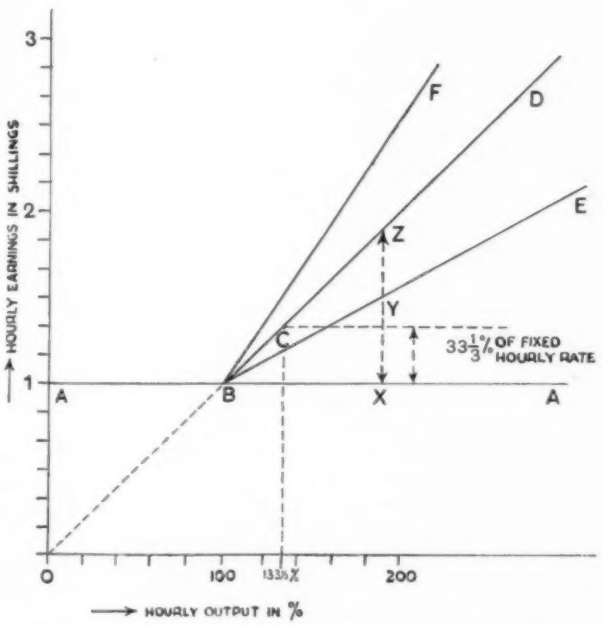
This brief explanation may be sufficient to show that the problem of fair piece-work wages, even when it can be solved satisfactorily, is by no means an easy one : it needs a firm, but just, mind, trained technically, economically, and psychologically, and it needs patience, where it has to be introduced, perhaps replacing an old and wrong system, and constant attention where it is already in use ; for with changing working conditions—and they will never be constant in a really up-to-date works—the prices must change correspondingly.

Finally, it should not be forgotten that this piece-work wage system should be connected with a guarantee of a minimum wage, usually the hourly rate, fixed by agreement—i.e., perhaps 75 to 80% of the hourly earning in piece-work—a fair protection for the men against circumstances which may arise through no fault of theirs. When a man is not capable of increasing his earnings above this minimum level, say, during two or three wage periods, he should be removed to another more suitable workplace ; but another man who can and does earn more than the expected average—the excess may be as big as possible—must not be disturbed under any circumstances.

Other Wage Systems

The difficulties of building up, introducing, and maintaining a fair piece-work system, and also the wish to have in the wage system some incentive, as is undoubtedly contained in piece-work prices, have led to many other systems, such as payment by result, premium, bonus, incentive, etc., and much has been written about these systems, their advantages and disadvantages to each other, to the hourly fixed rate and the pure piece-work system. I have had many opportunities of studying these systems, both theoretically and in practice, but as a definite solution I could not recommend any of them, and only in rare cases have I used them as a temporary measure.

They are too complicated when calculating the earnings of the men ; they are too difficult to be easily understood by the men, and therefore the suspicion of the men is likely to arise ; they render more difficult the estimating of costs ; and they are unfair either to the men or to the works. In nearly all cases they consist in the distribution of earnings, in excess of the level which had been expected between the men and the firm, whereas in the piece-work system this excess is given entirely to the worker whose higher efforts have produced it. The works receive their share by the increased output and the correspondingly lowered overhead costs, and are not entitled to obtain a second part at the cost of the men. Where, however, such a wage system is built up with the idea of increasing the excess of earning above the average, which is not proportional to the increase of output as with the piece-work system, but a rapidly increasing proportion, either the worker is over-exerted, the plant is worked too hard, or, mostly, both occur and a breakdown is invariably the result.



(Output with average performance taken as 133⅓% according to agreement)

Line A–A represents the fixed hourly rate system.

Line A–B–C–D represents the piece-rate system with a minimum wage = fixed hourly rate.

Line A–B–E represents a premium system, the men and the works sharing the excess of earning—for example, X–Y = share of the men ; Y–Z = share of the works.

Line A–B–F represents a premium system with an excess of earning increasing quicker than the output.

Fig. 8.—Showing principle of various systems

These are the reasons why, in principle, I am against all these systems, and I have known many cases where they have been introduced with great enthusiasm and hopes, but had to be abandoned after a long or short trial, leaving both the management and men disappointed, and a situation giving more trouble than that experienced when the original scheme was introduced. I would not be surprised if some readers could give examples of an opposite nature, but special circumstances may have been the reason, as, for instance, a change from an incorrectly built up and badly applied piece-work system, and designed to avoid some of the mistakes made.

Under these circumstances, I do not propose to consider these premium systems in greater detail, but the accompanying illustration, Fig. 8, shows the principles of the various systems which I hope will be understood without further explanation.

The Tonnage Bonus

One kind of "payment by results," however, is noteworthy, and to which I wish to direct readers' attention. This system is so often found in metallurgical works, despite the fact that a short consideration shows it does not satisfy the simplest demands which must be made to a system pretending to be a payment by result—i.e., the tonnage bonus. If the expression, "payment by result," is a logical one, it can only mean that somebody, in this case the workman, is paid according to the result obtained by his work; and the piece-work system, as explained above, is a real payment by result. But the produced ton is only a correct measure of the work done in rare cases—i.e., if a real mass production without change of quality, dimension, production method, etc., takes place. In all other cases a ton of the one class is not equal to a ton of the other, and therefore the ton cannot be a fair measure of the work of the men. Moreover, the workers have not the slightest influence as to which class of product has to be produced; perhaps in one week the products to be delivered involve increased work and increased time in consequence; the earnings in this week will be lower. Of course, in another week the reverse may occur and the earnings exceed the average, and in the long run it will be equalised; but there are these fluctuations which irritate the workman with his small budget, and create, perhaps unconsciously, an ill-feeling, because he knows that he has done his job properly week after week in the same manner.

Here is a problem which is of much greater importance than is generally assumed, and we will discuss in the next article how it should be tackled in order to obtain a fairly reasonable result.

Modern Forging Methods

Some impressions on modern forging methods were given by Mr. F. J. Somers at a recent meeting of the Staffordshire Iron and Steel Institute in which he discussed the production of medium and heavyweight forgings used in shipbuilding and general engineering trades. An abstract of his views is given.

THE secret of production in any forge is the furnace capacity. The forging unit itself, whether press or hammer, represents the largest single item of expenditure in forge shop equipment, and if this unit is to earn a proper return for the capital expended upon it, it must be able to work continuously. This can only be achieved by having "heats" constantly ready for the anvil, so that one can follow another day and night. Furnace capacity however, may be able to deal with the requirements of the forge units without difficulty, but this was not enough. It is not possible for the human element to stand the strain of continuous production, and this can only be obtained by suitable and proper mechanisation, and it was this point Mr. Somers stressed.

Mechanisation in any forge can be absolute. The furnaces can be charged by machines, heats brought from the furnaces to the forging units by machines and other machines can undertake all the manipulation necessary at the press or hammer. If mechanisation is carried out to the extent indicated, there was no reason why a forging unit should have to stand idle for one minute, except when repairs are necessary, and the strain imposed upon the human factor by continuous production would be largely eliminated. High-pressure production of this nature has been made possible by a machine of American origin, known as a manipulator.

The usual practice is to arrange that two of these machines should serve each forging unit. One machine is used for working at the press or hammer, while the other is free to charge furnaces, bring heats to the anvil, and also to assist in manipulating when necessary. If only one machine were in use, the charging of the furnaces, feeding the anvil, etc., could be done by overhead travelling cranes. These cranes can be fitted with automatic lifting devices so that there is no necessity for slinging by chains or man-handling of any description. On the other hand, this method of production restricts the type of furnace which can be used to two types, the pit type or the trolley type, both of which can be charged by overhead methods. The former is the cheaper to construct and is very economical in fuel. The ingots were placed in these furnaces on end, either one or two large ones at a time, or, if this was not convenient, a greater number of smaller ones can be charged.

The trolley type of furnace is constructed so that the hearth can be moved in and out of the furnace. The raising and lowering of the furnace door, the movement of the trolley, the picking up of the ingot and the depositing of it at the forging unit, where it can be taken over by the manipulator, are entirely automatic, and the whole operation need only take the short period of one minute.

In America, using this type of equipment, there are forges with one or two forging presses of 1,000 to 2,000 tons capacity and one or two steam hammers, capable of an output of 3,000 to 4,000 tons of miscellaneous forgings per month. By miscellaneous output, the reference is not intended to mean a continuous output of material of the same shape and character. One plant in the United States is engaged on such repetition work, in which one press alone is exceeding the output mentioned by three times. Another plant at Canton, Ohio, employs only three men per shift of eight hours and is producing 1,000 tons of forged bars per month.

Modernisation on the lines outlined, would give far greater outputs with no increase in personnel and would tend to make prices more competitive, which would obtain for forgings works in this country a far larger share of the world's forging trade, and so make the initial capital outlay of such plant worth while. It should be remembered that this country is a part of a Commonwealth of Nations containing a quarter of the world's population and is the natural market for the goods supplied by this country.

The forging industry is vital to the nation's defence, and a switch over to war-time conditions would throw a tremendous strain on this industry as at present organised. On the other hand, if this industry was properly organised, and properly equipped with the plant necessary to enable it to compete in world trade, to increase production whenever and wherever necessary, and to be ready in case of national emergency, it could more than supply the demands made upon it without wastage of man power.

Practical Notes on Drill Grinding

By L. Sanderson

Some indication regarding proper grinding practices for twist drills is given with the object of reducing troubles encountered, particularly the fracture of drills which frequently occur after a drill has been ground and returned to the machine. Lip clearance, lip angles and lengths, and point thinning are discussed.

COMPLAINTS of the fracture of twist-drills in use can often be traced to errors in the grinding of the point of the drill. Complaints of this type suggest that bad grinding usually occurs after a drill has been ground up and returned to the machine, the tool then crumbles or blunts at the edges, does not centre accurately, or the hole it drills is of greater dimensions than the drill itself. The drill may even break in two. In such circumstances it is easy to return the drill to the manufacturer with a declaration that it is defective. Actually, however, the great majority of these troubles are due to bad or imperfect grinding.

The first essential is a proper drill-grinding machine, which, if set with a little attention to detail, will make certain that the tools are invariably ground in the correct fashion. Nevertheless, not every shop possesses a machine of this type, and the grinder works by hand. This means that the final performance of the drill depends largely on his personal capacity.

In actual grinding, an important consideration is the avoidance of excessive pressure. This sets up severe local heat, thereby causing an irregular expansion of the steel, and possibly fracture due to the formation of fine cracks, which enlarge under stress in use. It is advisable to grind the drills on a free-cutting wheel provided with a full and effective water supply. If the water is inadequate or of limited flow, and these defects cannot for special reasons be remedied, it is definitely advantageous to grind the drills quite dry, but employing very light pressure. In this way the drill can be prevented from becoming excessively hot.

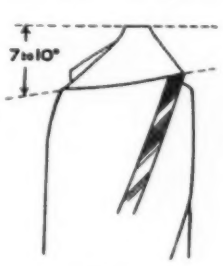


Fig. 1.

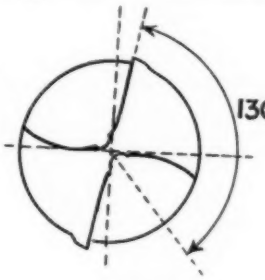


Fig. 2.

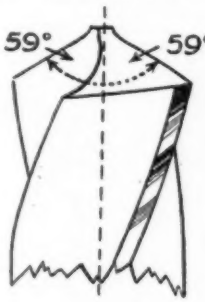


Fig. 3.

Fig. 4.

Fig. 5.

Cracks in drills due to grinding may be invisible to the naked eye, or almost invisible, but when the drill is set to work, they extend and expand until eventually the drill breaks. For similar reasons, if the drill has in some way or other grown too hot in operation, it must on no account be cooled by pouring cold water over it, or immersing it in cold water. It should be allowed to cool down slowly without assistance. The sharp contraction caused by sudden cooling would once more set up unequal stresses and cause fracture.

Drill grinding is divisible into three main sections—lip clearance, equal lip angles and lengths, point thinning. Lip clearance is the relief with which drill cutting edges are provided, so that they may penetrate into the work. If this clearance is not given, the entire surface X in Fig. 1 will make contact with the material, and it will be obvious from this that the cutting edges will be quite unable to cut into the metal.

In general, it is advisable to give the drill a lip of clearance of seven to ten degrees, and this recommendation should be closely followed. If a greater clearance than that given is adopted, the cutting edges will not be adequately supported at their rear, so that it is almost certain they will break down or chip off. If the clearance is less, the cutting edges cannot penetrate the metal, and the drill will only rotate without piercing, with the result that it will, in all probability, split up the centre.

The clearance angle stated applies to the angle at the drill circumference only, but it should be gradually increased towards the centre or bridge or the drill, until the line across the bridge constitutes an angle with the cutting edges of about 130°. (See Fig. 2.)

The most suitable lip angle for normal work is 59°, as in Fig. 3. Should this angle be greater than 59°, there will be difficulty in getting the tool to centre. If it is less, the drill will not be quite strong enough at the point, and it will absorb more power in driving on account of the extra length of cutting edges. Moreover, the flute is so designed that it provides straight-line cutting edges when the lips are at an angle of 59° with the drill axis. If the angle is more than 59°, concavity in the cutting edges will result. If less than 59°, convexity will arise. Of course, it is not argued here that a degree or even two makes a vital difference. When the angle is identical for both lips, the difference thus made will not be critical.

If the drill has straight line cutting edges, it will produce a drilling of spiral form and extreme length—so long as the material on which it is operating is not of a crumbling type. Concave cutting edges result in the outer particles of the drilling crowding towards the centre and the inside particles towards the circumference. The drilling will then tend to break up into small pieces. When the cutting edges are convex, the reverse action takes place, outer particles crowding to the circumference and inside particles to the centre, again with a broken-up drilling as the result. Thus, the formation of the drilling is not only a good indication of the efficiency of the lip angles, but it is also a possible cause of breakdown. If the drilling break up readily into small pieces they clog the hole, prevent the rapid dissipation of the heat generated in drilling, hinder the coolant from penetrating to the true cutting edges, and so lead to bad performance and even breakdown. Thus, the correct degree of lip angle ensures rapid freeing of the hold from drillings, and thus the carrying away from danger points of the heat generated, a great deal of which is in the chips.

Secondly, both angles should be equal, as shown in Fig. 3, and the two lips should also be equal in length.

Let one or two instances now be considered, in which incorrect grinding has taken place. When the point of the drill is in the centre, but the cutting edges are ground to different angles, it will be found that one cutting edge is performing practically the whole of the operation, while

the other merely takes away a minute portion of material on the periphery of the hole. Since one edge is doing the whole job, the tool will soon have to be taken out for sharpening, too soon for efficiency and economy. Furthermore, the hole will be of larger size than is required, because the drill is being forced to one side.

When the cutting edges have been ground to equal cone angles, but are not of equal length, it will be found that the drill point is not in the same line as the axis of the drill. This means that spindle and drill are rotating on one axis, and the point of the drill is endeavouring to rotate on its own axis. What happens? The spindle wobbles, with the result that the bearings have to take up excessive wear, as does the drill, which will probably fracture, while the hole drilled will be enlarged.

When the cutting edges are not identical in length and have, also, unequal angles, and a point off centre, the conditions are just about as bad as they can be. The result is fierce stress on both tool and drilling machine, and breakage as the inevitable result.

The form of the drilling as a guide to the accuracy of the grinding has already been mentioned. Another indication is the following:—In drilling, a long, fair-sized drilling is sometimes seen emerging from one drill flute, while the other ejects only an undersized small one. This is a fairly sure sign of imperfect drill grinding, and the drill should at once be removed for examination of the point, followed by the remedying of errors in a further regrinding.

Some drill users advocate rounding the outer corners of the lips. While this practice may be beneficial when exceptionally hard and severe jobs are being drilled, giving a greater length of life per grind of drill, it is not particularly profitable in normal drilling practice, and may even be a disadvantage in certain instances. It should only be used when it is established that trouble has been caused by the sharp corners of the normal drill-point. Then the rounded edges will need to be provided with cutting clearance on the customary lines, which is quite simple. In general, these corners are not heavily stressed, but on occasion they may be overtaxed, and then rounding of the corners may do good. For example, there may be severe stress due to specially heavy break-through of the drill, and this may cause chipping of the corners. The rounding operation will add strength at these points. Again, the speed may be too high, and the normal corners may be burned. Corners rounded distribute the cut more evenly, and therefore even out the heat produced. It may thus be feasible to avoid, where desirable, a reduction in speed. Corner rounding may be helped by a reduction of the rake angle. This is particularly so where harder metal is being drilled than the standard drill is usually called upon to tackle. Corner-rounding is, however, useless for drilling manganese steel.

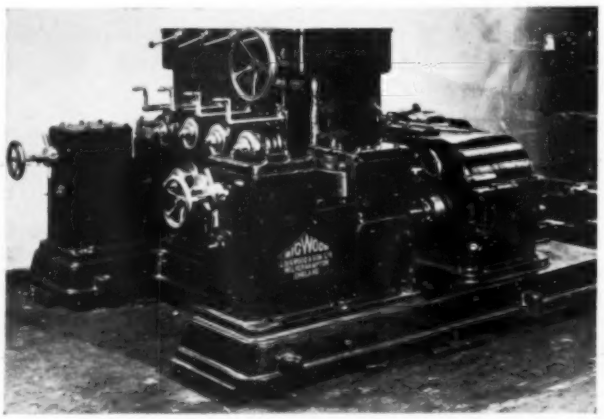
The thinning of the point is an essential operation, because the web of the drill is generally thicker than is desirable. The web gets thicker the nearer it comes to the shank, so that as the drill gets shorter through regrinding, more thinning becomes necessary. Otherwise, the pressure necessary to cause the tool to penetrate would be too great. It is important, however, that point-thinning should be effected equally on both sides, to make certain that the dead centre is still in the centre of the drill bridge. The thinning must not go too high up the web, or the drill-point will be made to lose strength.

The rake angle is that made by the spiral flute of the drill with the work (see Fig. 4). The drill manufacturer usually provides drills with the most suitable rake angle, which should not, usually, be altered when grinding. Sometimes, however, little or no top rake may be an advantage in drilling hard materials. The greater the rake, the acuter the wedge-angle, and therefore the weaker the cutting edge. When soft or medium materials are drilled, the normal rake angle of the drill cannot be improved, because it takes up less power in driving, and the metal is not hard enough to make the edges give way. But if the metal is hard, it may be advisable to lessen the rake-angle, as otherwise the edges might give under the severe stress to which they were subjected. The method of grinding to reduce the rake angle is shown in Fig. 5. This increases the wedge angle, and so helps the drill to withstand a severe feed pressure. If chilled cast iron is being drilled, there is nothing to bear the flat drill, which will stand extremely heavy feeds.

A Modern Shape and Section Straightening Machine

THE accompanying illustration shows a recent design of roller type shape and section straightening machine, suitable for dealing with angles up to 3 in. by 3 in. by $\frac{3}{8}$ in., and other sections of equal modulus. It is a well-designed and very liberally proportioned machine tool, possessing in a marked degree the rugged strength which is so essential for the duties it is called upon to perform.

The machine is of the eight-roll type, and in addition is fitted with vertical rolls on the ingoing and outgoing sides, the roll gears being driven through forged-steel machine-cut gears. The top rolls are provided with vertical and horizontal adjustment, and the top rolls are keyed on to the ends of the shafts, so that the shafts themselves rotate in heavy roller type bearings in the top chocks. Vertical and horizontal adjustment is made by means of handwheels, which are placed at the front of the machine, whilst heavy thrust bearings are fitted to take the end thrust.



A modern shape and section straightening machine by Joshua Bigwood & Son Ltd.

The driving gears are totally enclosed, and the roll bearings are provided with seals to retain the oil and prevent the entry of scale and dirt. One of each pair of vertical rolls is driven, the drive being taken from the main gearbox of the machine. An automatic system of lubrication is fitted to all bearings. Driven by a 25-h.p. motor, with an approximate speed of 960 r.p.m., straightening is effected at the rate of about 120 ft. per min.

The machine, which is completely Timken equipped, approximately thirty Timken bearings being used, is manufactured by Joshua Bigwood and Son, Ltd., of Wolverhampton.

Lincoln Arc Welding Foundation Papers

THE trustees of the James F. Lincoln Arc Welding Foundation announce that 109 of the more important papers submitted in the $200,000 Award Programme will shortly be published in book form. The papers constitute a large and valuable source of scientific study, research and information respecting the process of welding and its application and the decision to publish them will make the work incorporated in the papers more generally available. The book, which will be priced at $1·50 post free in the United States and $2·00 elsewhere, will be available early in February.

Reviews of Current Literature

Steel and its Heat-treatment

THIS is the fourth edition of this valuable work. It deals with the principles, processes, and control relating to the heat-treatment of steel in general, whether plain carbon or alloy. Apart from the chapter on nitriding which was added in the 1935 edition, the subject matter of this book had not been materially revised since 1927, but new information has become available, various principles have received verification, and major advances have been made. There is, to-day, an understanding of the significance of the grain coarsening tendencies of steels and developments in their control ; the use of controlled atmospheres, the rise of high yield-point low alloy steels ; forced circulation in tempering furnaces ; the use of copper as an alloying element in steel, and a generally clearer conception of the mechanism of heat-treatment and the specific effects of the alloying elements.

These have meant the introduction of new chapters and the condensation of elimination of other material. The task of the Battelle Memorial Institute when revising the book will be appreciated by the phrasing of the preface, in which it is stated that symposia on special topics, held by technical societies, supply compact information in especially convenient form. Behind these compilations are thousands of articles in which the information was originally presented. This very profusion, although of immense value when all available information upon a specific point is necessary, is a drawback when what is desired is a broad picture of the state of the art of the heat-treatment of steels and an understanding of the fundamental principles involved, a picture that will enable readers to apply the summation of known facts to the problems he personally faces. Hence, the effort in this revision, as in the previous editions, is to present the whole topic from a consistent, unified point of view, in which the need of the practical man for pertinent information is never lost sight of.

The three sections of the book deal with metallurgical principles, surface reaction processes, and control of heat-treatment operations. The first includes general annealing practice ; spheroidising, normalising and " austempering " ; principles of hardening ; precipitation hardening, and grain size. The second section deals with case carburising ; heat-treatment of carburised steels ; controlled atmospheres and cyaniding, nitriding, surface hardening and cooling. A marked inclusion in the third section is that of the human element, and this section includes discussion of proper heating in forging and rolling practice, fuels and furnaces. application of heat, and control of the cooling phase.

It is perhaps hardly necessary to add that publication is well and liberally illustrated with photographs, charts, diagrams, and tables, and those familiar with previous editions will appreciate that the present edition has been brought up to date and its high value maintained.

By D. K. Bullens and the Metallurgical Staff of the Battelle Memorial Institute ; published by John Wiley and Sons, Inc., New York, and Chapman and Hall, Ltd., 11, Henrietta Street, W.C. 2 ; price 22s. 6d.

Aluminium Bronze

DIFFICULTIES formerly experienced with aluminium bronze have been largely overcome, and to-day the casting and working of this valuable material are being handled in regular commercial production, with the result that its use has increased, but for some unaccountable reason the industrial application of the range of copper-aluminium alloys embraced by aluminium bronze has not yet reached the proportions of certain other copper alloys. It is probable that lack of appreciation of certain fundamental features, which have a marked influence on the manufacturing technique, has been the principal reason for the somewhat limited uses of these alloys. This book on the subject will help to remove difficulties which may have been encountered in casting or working aluminium bronze, and will assist in the wider use of a really valuable material.

Essentially, copper-aluminium alloys in which the aluminium content may be as much as 14%, but is usually not more than 10%, aluminium bronzes also contain appreciable quantities of iron, manganese, nickel, and other elements are also frequently added. Probably the most useful range of these alloys fall within the α and β range ; these, when in perfect general condition, give maximum mechanical characteristics, ranging from 38 to 41 tons per sq. in. ultimate stress in sand castings to 51 tons in chilled castings and forgings. This high-tensile strength enables a reduction in weight to be obtained in castings and forgings usually made in other metals and alloys ; an important factor which has an appreciable effect in reducing the cost of parts made in aluminium bronze.

Apart from high-strength characteristics, which these alloys possess, they are particularly attractive, because of their resistance to corrosion, especially to attack by sulphuric acid, sea-water, and other corrosive media. It is rather surprising, therefore, that the aluminium bronzes are not used to a greater extent where these outstanding qualities can be used with advantage. At present, one of the most important uses of aluminium bronze is in the construction of equipment for pickling steel in sulphuric acid. Tanks, crates, racks and baskets, as well as hooks, slings, wire rope, chain, and various tank fittings are made of these alloys. Equipment for the chemical industry, including pumps, stills, valves, autoclaves, and piping are made of these alloys. Many ventilating systems find it profitable to employ aluminium bronze for ducts and fans, particularly in the systems used in pickling rooms, storage-battery rooms, rubber vulcanising plants, over linotype melting pots in printing works, dry-houses, laboratories, and other places where corrosive vapours are encountered. Although only brief reference has been made here to some of the applications of this range of alloys, from the point of view of strength, resistance to oxidation and corrosion, the aluminium bronzes are almost unique in the range of copper alloys and have many applications outside those for which such alloys are normally employed.

In this book an effort has been made to bring together all the up-to-date reliable information about the aluminium bronzes, their outstanding properties, and modern working and casting technique, with the result that a most informative and useful work has become available to all interested in this range of alloys. It is admirably produced, and contains a useful bibliography. No charge is made for a copy of this publication, but the publishers ask readers to make application on their firm's headed notepaper or otherwise give satisfactory evidence of responsible status or genuine interest.

Published by Copper Development Association, Thames House, Millbank, London, S.W. 1.

Introduction to Metallurgy

ESSENTIALLY for students, this book provides a solid background to this subject, but leaves him under the necessity of obtaining elaborations and developments from specialised textbooks, which is a wise principle in dealing with this subject and its multitude of specialised branches, each with its own voluminous literature. It includes a number of examples of technical calculations, and a list of problems is appended to each chapter, the author contending that the solution of illustrative problems is the best method of fixing the principles in mind, whilst giving a proper conception of the quantitative aspects of the science of metallurgy.

By dividing the contents into two parts, the subjects of adaptive metallurgy and extractive metallurgy are dealt with in a thorough and logical manner. The six chapters under the former heading discuss the structure of metals and of alloys ; the physical properties, shaping, and heat-treatment of both metals and alloys, and a section on the

industrial metals and their alloys is informative as well as providing a useful reference chapter for general purposes. The second section deals with the sources of metals, ore dressing, hydrometallurgy, pyrometallurgy—considered from the points of view of chemical principles, heat, and processes—electro-metallurgy, sampling and related topics, and, finally, production of the industrial metals.

The student will certainly find the introduction and the opening chapters of special value; crystal lattice, atomic mass and volume, grain size and growth, plastic flow and thermal analysis being treated in an exemplary manner and without which the student would not be able to proceed with any facility.

The chemical principles involved in pyrometallurgy form one of the chapters in the book that will be of particular value to students; this being broken into three parts—chemical principles; a study of heat, including fuels, combustion and pyrometry; and a brief discussion of the important processes. The first of those sections covers chemical affinities and equilibrium; reaction velocity; the countercurrent principle; stoichiometry—the gas laws; thermochemistry; reaction types; metathesis—acids and bases; and the final section on metallic compounds is one well worth studying by all taking more than a superficial interest in the subject. Here, as in other chapters, the exercises are practical, straightforward, and educative in themselves.

However, in reviewing a book which covers such a great amount of ground in an extremely clear fashion, it would be invidious to suggest that any one chapter is of more value than another, and the very brief mention we have made of one or other chapters is merely indicative of the scope of the book and the author's policy of preparing such a volume to serve two primary purposes—to give a comprehensive view of the field of metallurgy as a whole, and to acquaint the student with metallurgical idiom and give him the necessary vocabulary for the understanding of specialised treatises on the various branches of metallurgy. The book succeeds in this two-fold purpose.

By Joseph Newton; published by John Wiley and Sons, Inc., New York, and Chapman and Hall, Ltd., 11, Henrietta Street, W.C. 2; price 20s. net.

Journal of the Electro-Depositors' Technical Society—Vol. XIV

THIS volume contains twenty-four papers presented either at London or Birmingham during the 1937-1938 session of the Society, and discussion on twelve of those papers is included. The papers cover work on the measurement of thickness of electro-deposits by the drop test; the removal of nickel electro-deposits from steel by anodic treatment in 50% (volume) sulphuric acid solution, with an applied potential not exceeding 2·0 volt; commercial methods of stripping, particularly for chromium, nickel, and copper; the stripping of chromium deposits for thickness measurement; the electro-chemistry of protective metallic coatings, in which an attempt is made to clarify the position regarding the electrode potentials of metals under the non-equilibrium conditions obtaining in corrosion processes; fundamental problems in nickel-plating; magnetic tests for plating thickness or its measurement are the subject of three different papers; and there is a most interesting, though comparatively short, paper on chromium plating in the printing trades, particularly in its application to the copper cylinders used in the photogravure rotary process. Here it is shown that the average life of a copper cylinder is about 15,000 copies for maintenance of proof copy standard, but with the same conditions of working a chromium-faced roller will give about 120,000 copies, especially if the machine is printing from a reel of paper in contradistinction to a sheet-fed machine. Then, too, the nature of inks used is shown to affect chromium far less than the bare copper roller.

Other papers deal with various aspects of plating practice; the anodic treatment of aluminium and its alloys, and a volumetric process for the determination of cobalt and nickel in the presence of each other is described and discussed.

The journal is well illustrated with diagrams and charts and a limited number of photographs. It is published by the Society and copies are obtainable from the Hon. Secretary—Electro-depositors' Technical Society, Northampton Polytechnic Society, St. John Street, Clerkenwell, London, E.C. 1. Price to members, 15s.; to non-members, 21s. net.

Solution of Electrolytic Manganese Problem Enables Recovery of High-Purity Metallic Manganese from Low-grade Ores

THE successful solution of the electrolytic manganese problem, which provides a method for the recovery of high-purity metallic manganese from low-grade ores, devised by the Bureau of Mines, Department of the Interior, is recorded in a progress report recently published.* The process for the electrolytic production of manganese from its ores as it now stands, and which is regarded as a commercially feasible one, is different from that described in previous publications. It consists essentially of several steps, which may be briefly outlined as follows:—

Roasting the ore in a reducing atmosphere to convert the higher oxides of manganese to manganese oxide. This is done in an externally heated rotating kiln, similar to that used in the Caron-Clevenger process. The ore must be cooled in a reducing atmosphere.

The roasted ore is then leached with the spent electrolyte from the electrolytic cells. This spent electrolyte contains about 2½ to 3% of sulphuric acid. This insoluble is removed by settling and filtration.

The leach liquor is then treated for the removal of impurities. Iron and arsenic are removed by the addition of manganese dioxide, which occurs as an anode product during electrolysis and agitation with air. The precipitated ferric hydroxides with the occluded arsenic are removed by filtration. The solution is then treated for cobalt and nickel, which have been found to be highly detrimental to the electrolysis of manganese.

After filtration, the solution then passes to the reservoir feeding the electrolytic cell. The cell has lead anodes and stainless-steel starting cathodes separated by canvas diaphragms. It is fed continuously, and the spent anolyte is run off and filtered to remove some manganese dioxide that is formed at the anode. The spent anolyte returns to the leaching circuit.

The current density is approximately 20 amperes per sq. ft. The energy consumed averages from 3·2 to 3·7 k.w.-hours per lb. of metal. Analysis of the metal showed 99·63% manganese. The principal impurity was sulphur from the electrolyte. Other impurities were in the third and fourth decimal places. Several hundred pounds of this metal have been produced for experimental purposes.

Magnesium Metal

A general survey relative to the production of magnesium metal, made in co-operation with the State College of Washington, emphasised the importance of investigating the direct reduction of magnesium oxide by carbon and purification of the product by distillation and of studying the production of anhydrous bichloride of magnesium by treating a mixture of magnesium oxide and carbon with chlorine.

As a preliminary step, tests were made on two types of concentration. Selective calcination followed by mulling or heating and then by screening gave good results, as did flotation when certain conditions were maintained. A cyclic process for leaching a calcined ore, precipitating pure magnesium carbonate, and recovering the reagent for re-use in extraction was worked out. Considerable progress has been made in experimentation aiming at the production of anhydrous magnesium chloride.

Copies of this paper, designated as "Progress Reports—Metallurgical Division, No. 24, Electrometallurgical Investigations," may be obtained from the Bureau of Mines, Washington, D.C.

Progress in Chilled and Grain Roll Manufacture

By W. H. Lewis

Changes in roll plants were discussed by Mr. Lewis in his presidential address at a recent meeting of the Staffordshire Iron and Steel Institute in which he referred to the improved working conditions and equipment and also the improved personnel. The main features of his discussion are given in this article.

ONE important change in roll foundry practice is the advent of the metallurgist, with technical training and with the knowledge which the sciences and practical research have provided for application to the craft. This does not mean however, that science has replaced craft in industry. In the author's opinion the function of science is to replace ignorance and guesswork by more precise knowledge. Roll making is not now, and never will be a science, and the metallurgist who produces rolls is still a craftsman with a tremendous advantage in training and knowledge over his predecessor. The works' laboratory has become a necessary instrument in the control of routine operations as well as a department of research for the improvement of works' practice and the quality of the product.

Cold blast pig iron is still the basis material having inherent in itself the combination of strength, toughness, hardness and chill necessary to produce chilled rolls. Many investigations have shown that mixtures of different irons, although they may have the same final analysis, can in similar castings, made under identical conditions, have very dissimilar structures and mechanical properties, and research has discovered scientific explanations for some of these anomalies. Among those not yet fully explained however, is the difficulty of reproducing in other irons, all the characteristics of cold blast iron which contribute to the making of a good chilled roll.

The basis materials used in roll making therefore, have changed little. The significant advance is in the more precise selection by analysis instead of by fracture and sound tests. Two advantages are obvious—even cold blast irons giving the same fracture and chill on test can vary widely in analysis, and a freak analysis can seriously affect the relation between chill on the test bar and chill on the roll. Selection by analysis has done much to reduce this disturbing factor. Secondly, it is only by analytical control of mixtures that the elements can be balanced to give the wide range of roll qualities now called for. Further, the proper effect of the alloys used for special purposes can only be obtained by an equally careful control of the alloys themselves and of the elements normally found in the basis mixture.

The air furnace is still the most common and most suitable melting unit. Control by analysis of the charge, knowledge of the normal losses by oxidation, and checking of temperature by optical instruments have much improved the standards of melting practice. The same chill test bar is still used to check the melt. In addition, particularly in the case of the many types of highly alloyed rolls, a bath sample is taken to the laboratory to check analysis and to ensure that the specified hardness will be obtained. One difference between Staffordshire melting practice and that of other districts and countries may be of interest. The general practice elsewhere is to charge the cold furnace and then commence firing. In Staffordshire, the furnace is heated up first and charged when hot, firing being then resumed. Melting from a cold charged furnace is much more economical and often shows a 50%-saving in fuel consumption, but in this district it is believed that the advantages in control and in quality of melt obtained by using a new sand bottom for each charge and by the quicker melting time, outweigh economy in fuel.

Grain rolls range from 8 in. to 36 in. of mill centres, and from a few cwt. to 20 tons in weight. Chilled rolls run from 6 in. to 44 in. in diameter, from 7 in. to 14 ft. in length of barrel and from 1 cwt. to 40 ton in weight.

The ordinary grain roll is now limited to use in section and bar mills, sometimes for cogging, more often for roughing and finishing, where a large range of sections is produced and outputs required at one rolling do not justify harder alloy rolls. Better selection of the mixture and improved moulding technique have given a finer surface structure and a sounder casting. A small percentage of chromium is usual and the hardness ranges from 35° to 40° Shore. This type of roll is strong and tough and has good resistance to firecracking.

Alloy grain rolls vary in surface hardness from 40° to 60° Shore. Nickel, chromium and molybdenum are the principal alloys used. The finish of the rolled stock is improved. High alloy rolls are more liable than grain rolls to firecracking. It is essential with this type of roll to keep the surface at as low and as even a temperature as possible, by proper distribution of cooling water fed independently to each roll. In the United States, the greater tonnages and longer runs possible with less changing of rolls and the use of special mills for one type or a limited range of sections, created an earlier demand for high alloy rolls, with the result that their mill practice has been adapted to suit the new types of roll to a greater extent than is yet possible in this country.

Straight carbon and low molybdenum alloy chilled rolls form the largest proportion in tonnage and numbers of chilled rolls made. Surface hardness is from 55° to 65° Shore. These are still the most suitable types of roll for hot rolling steel plates, sheets and blackplates, and non-ferrous sheets in two and three high single mills.

High alloy chilled rolls are made with surface hardness up to 90° Shore. Again the alloys used are nickel, chromium and molybdenum. For hot rolling, the use of alloy chilled rolls is limited to small sizes for strip and light sections, and to applications where they can work within very close limits of temperature. They can be surface ground to a high polish for the cold rolling of both steel and non-ferrous flat work and they give a degree of finish impossible with the ordinary chilled roll.

The scleroscope hardness test has become a standard method of measuring the surface hardness of rolls and an important part of the specification for rolls for special purposes. Unfortunately, machines of the same type do not always give equal hardness readings on the same surface, even when they agree on the standard testblock. There is a pressing need for standard chill blocks covering the full hardness range of chilled rolls and for the universal adoption of one type of instrument for roll hardness, if specifications are to be checked satisfactorily. Experience to date also indicates that hardness tests are not always reliable as a measure of the finish obtained on the cold rolled material. This may be due to one or all of several reasons. The scleroscope instrument is sensitive to the degree of polish of the surface. It measures only superficial hardness and not depth of hardness, which is equally important if the surface has to resist marking due to high pressure. The instrument gives no indication of the

surface structure. Chilled rolls work harden in use, and some types of alloy chill rolls do so more than others.

The designing of roll passes to produce from the ingot through cogging, roughing and finishing mills to-day's immense range of rolled sections is one of the crafts which has been least influenced or assisted by science or research. It is true that some fundamental principles based on mathematics have been enunciated, and many empirical formulæ based on experience have been devised for specific purposes, but there is no general theory of pass design to which all examples can be referred and related. The expert roll designer seems to be for the most part dependent on long practice and experience in section rolling and for the rest, born with an aptitude for correlating and assessing the value of the innumerable variables which have to be taken into account. The craft and methods of the roll designer have changed only to the extent that the ever increasing varieties of sections produced have enlarged his experience.

Science and the knowledge derived from scientific research have been largely responsible for the great progress made in works practice during this century. In the case of cast iron and steel for example, analysis and the iron-carbon diagram, and metallography have combined to aid a long line of distinguished metallurgists to give us a new conception of their nature and a new power to control their properties and improve their uses. To-day, we have arrived at a point when scientific knowledge seems to be in advance of the ability of industry to use it. It does appear important therefore, that the energies of research and technical institutions should be directed as far as possible to applying this vast fund of knowledge to industrial purposes, and that industries should co-operate with such bodies as far as possible for this purpose.

Further, the author would suggest the increasing necessity for co-operation between manufacturers and the users of their products, particularly in cases such as the one being considered, where one technical industry is serving another. In the case of rolls, for example, endeavour has been made to indicate the variety of conditions under which they work and the necessity for compromise in the compositions and properties of the materials used to obtain the best results. Frank and full collaboration between users and makers must be established if we wish to stimulate industrial progress.

Catalogues and Other Publications

Data concerning the grades, properties and aspects of manipulation of the "Nitralloy" group of steels and their application is given in a new brochure on "Firth-Brown Nitralloy Steels" published by Thos. Firth and John Brown Ltd. Features of the nitriding process, the many grades of Nitralloy steel and their physical properties are given in detail; the latter including hardness at elevated temperatures, specific gravity, electrical resistivity, remanence and coercive force, so-efficient of expansion and resistance to fatigue.

The chapter on manipulation and fabrication covers forging operations, drop stampings and hot pressings, welding—in which it is stated that, generally speaking, the atomic hydrogen process gives the best results—core hardness, machining, nitriding and surface decarburising. Manufacturing procedures are discussed and the application of Nitralloy steels in a large number of industries is outlined.

A new chart to show approximate relationships between hardness values determined on "Rockwell" and "Rockwell" superficial hardness testers and the values determined by other hardness testers, such as Brinell, has been published by the Wilson Mechanical Instrument Co., Inc., of New York, and copies are available to readers from George H. Alexander Machinery, Ltd., of 82-84, Coleshill Street, Birmingham, 4.

It is pointed out that these comparisons or conversions can only be approximate as the tables must of necessity be based on the assumption but the tables should be of considerable value in giving comparisons of different hardness scales in a general way.

Turbine De-scaling

IT was found that the operating efficiency of two multistage steam turbines had dropped by more than 50% from their original output of 350 h.p. each at 3,500 r.p.m. They had been in service for several years, steam being produced in four 250 h.p. boilers rated at 200 lb. sq. in. pressure and operated at 185 lb. sq. in. Although the raw water was generally untreated it was occasionally treated with alum, but this apparently in a very haphazard manner. The turbines became badly clogged with scale. Handscraping was considered but the cost appeared uneconomic in view of the age of the turbines and the outlay which new turbines would involve.

Examination of a third turbine rotor which had been scaled and placed on one side previously showed that the scale contained about 25% silica. Entrikin* states that sections of this rotor were removed and the blades treated with various strengths and temperatures of hydrochloric acid. This acid was inhibited with less than 1% of certain organic chemicals. As a result of these tests it was ascertained that the scale was about one-fourth silica and three-fourths carbonates. The boiling acid did not appear to damage the iron rotor or the brass blades but the scale was either loosened or dissolved by lower concentrations of the acid.

The two turbines were then acidized, the inhibited acid being pumped into the turbine with sufficient steam to rotate the rotor at around half speed, no attempt being made to control the dilution of the acid with steam, but 2 gallons of acid were admitted each hour, a total of ten gallons being used on the first turbine. To try and dislodge any scale that had been loosened but not dissolved, heads of very wet steam were sent through the turbine every quarter of an hour. Later examination showed that about one-third of the scale had been removed completely and the other two-thirds had been loosened, but this remaining scale could not be dislodged with streams of high-pressure water.

In treating the second service turbine about 50 gallons of inhibited acid were employed, over a period of 8 hours. Examination showed that much of the scale between the small blades had been loosened but not removed, and that all the rust and scale from the shell had been dislodged. In neither case was there any appreciable effect on the metals of the turbine.

Subsequently, both rotors were treated by sandblasting for about three hours each; this removed the softened scale without erosion of the blades or rotor. Possibly, the sandblasting would have removed the scale without the acid treatment, but the softening of the scale made the removal easier.

These two turbines were then kept practically scale free, over a period of a year, through conditioning of the feed water; the total alqinity of the water was kept below 200 p.p.m. by adding 2·5 lb. of sulphuric acid to every 1,000 gallons of water; a continuous blow-down system was installed and the condensate checked by conductivity methods for the production of nearly solid-free steam.

It was concluded from this work, largely regarded as experimental, that inhibited hydrochloric acid could be employed on steam turbines without damage to the metal parts and that if the scale in a turbine is nearly free of silica, satisfactory cleaning can be done by the use of such acid process, but that if there is a carbonaceous scale containing as much as one-quarter silica then acidizing alone is not sufficient. The acid softens the scale if it contains carbonates and thus makes it easier for removal by sandblasting. In the tests mentioned, the blasting was carried out with 40-mesh hard sand and a pressure of 125 lb. sq. in. The two turbines treated generated full power again, after descaling.

* John B. Entrikin, *Ind. and Eng. Chem.* 1279. 11. 1738.

Business Notes and News

Birmingham Electric Furnaces Limited

Gas-Fired Furnaces

The success of the many types of mechanically-operated furnaces designed and produced by Birlec, with special reference to those with controlled atmospheres, has resulted in many requests being received for the supply of similar furnaces—gas-fired—for use under conditions where electrical energy is unduly expensive or even unobtainable, and where cheap gas is available.

The advent of the radiant tube gas-fired heating element has now made it possible to use gas as the heating medium for such furnaces, and consequently Birmingham Electric Furnaces Ltd. have, after careful consideration, decided to widen their field, and to undertake the manufacture of certain types of gas-fired furnaces. In some circumstances a combination of electric and gas heating will be offered. Most of the gas heating will be by means of radiant tube elements, the design and patent rights of an exceptionally efficient type being possessed by the Company.

Birmingham Electric Furnaces Ltd. inform us that whilst in certain cases gas-firing can be used as an alternative to electric heat, it is their belief that in very many applications the electric method offers advantages unobtainable by combustion methods, and for this reason they have no intention of offering gas-firing with all types of furnaces, but will restrict themselves to those types where, under certain economic conditions, they can recommend them with confidence.

International Tin Research and Development

The International Tin Research and Development Council have moved their office from 378, Strand, to Fraser Road, Greenford, Middlesex. New laboratories are in course of erection on the same site and should be in use early in 1939.

During the six years in which the Council has been in existence the demand on its resources has shown so healthy an expansion that these increased facilities have become necessary, and further extensions of the Council's activities are planned.

United States Steel Corporation

Large scale reorganisation and reconstruction have been carried out by the United States Steel Corporation which make the plant developments in this country seem relatively small. This Corporation has a large new sheet and tinplate works at Gary, with a capacity of 1,200,000 tons, and it has also new sheet and tinplate works at Irvin, Pittsburgh, with a rated capacity of 600,000 tons, and another at Birmingham, Alabama. All these works are new, and are considered to be the last word in technique for rolling steel slabs into strip by the continuous process. These are ultra modern plants and indicate that big steel corporations have decided to show what big scale developments can do.

George Kent Ltd.

The new year opened conspicuously for George Kent Ltd., as in the first working day, in addition to the usual run of business, the post included a very pleasing order from India for instruments to the value of well over £3,000 for a new steel works. Most of the instruments are to be of the ring-balance type.

1939 Convention American Foundrymen's Association

Cincinnati has been selected as the place of the 1939 annual convention of the American Foundrymen's Association, with the meeting opening on May 15 and continuing until May 18. The entire programme will be devoted to technical, management, and general interest sessions, shop operation courses, round table discussions and committee meetings, plant visitation, and social functions that add to the enjoyment of annual Foundrymen's Week.

Cincinnati was selected from among the several cities under consideration by a special convention committee, whose recommendation was unanimously approved by the Board of Directors. Among the determining factors was the importance of the metal manufacturing industry in the district.

Summers-United Steel Companies Arrangement

A considerable change has been effected in the old-established steel sheet firm of John Summers and Sons Ltd., of Shotton, Chester. When Richard Thomas and Co. Ltd. decided on the reconstruction scheme at their Ebbw Vale Works and the installation of the large continuous hot and cold strip mill, John Summers and Sons had to face the position of increased competition and ultimately decided to install a continuous strip mill of a similar type. The financial considerations involved have led to protracted negotiations which have resulted in a scheme under which the United Steel Companies Ltd. and the Bankers Industrial Development Company take part in the financing of the new mill.

The new mill is being erected to the design of the Mesta Machine Company of Pittsburg, U.S.A., and it is expected to be completed towards the end of the present year. When put into operation the new mill will largely replace existing plant.

Schneider-Creusot Sell Interest in Skoda's Works

It is understood that the French munitions firm of Schneider-Creusot has sold all its interests in the great Czecho-Slovak arms factories of Skoda. These interests are said to have been bought by the Anglo-Czecho-Slovak Bank—a semi-official Czech Government concern—which means that the Skoda works now fall under Germany's influence. These works equipped the whole of the Czechoslovakian army and were once reputed to manufacture about a quarter of the world's munitions. This transfer of French interests to Czech control is probably the first step to a working arrangement between Skoda and the Krupp arms works.

A New Steam Electric Locomotive

A new type streamlined electric locomotive, which carries its own steam turbine power plant and is claimed to be capable of twice the work of the ordinary type, was recently demonstrated on the test truck of the United States General Electric Company. The locomotive, which develops 5,000 h.p., is capable of speeds up to 125 miles per hour. The trans-continental lines over which the Union Pacific Railroad Company plan to use this locomotive include mountain grades and climatic conditions ranging at different periods of the year from well below zero to 100° F. Some of the mountain passes are at altitudes exceeding 7,000 feet above sea level.

Steam is generated in oil-fired boilers and the essential features of the locomotive include a geared turbine electric generating unit supplying electricity for operating six large driving motors on each side of the cabs. Light weight and limited space requirements necessitated some modifications of this power-plant equipment. The boiler uses forced circulation of the water and 45,000 lb. of steam per hour is generated to a pressure of 1,500 lb. at a temperature of 950° F. After passing through the turbine the steam is condensed and used over again.

An interesting feature is that electric braking is employed, whereby the driving motors act as generators when the train is coasting, and is particularly advantageous in reducing the wear on the brake shoes and in assuring the maximum of safety. From a metallurgical point of view many problems were involved and it is noteworthy that the cab construction is mainly of aluminium alloy, while electric welding has been used wherever possible in the fabrication of steel parts. This locomotive, which has been under construction for about two years, will be submitted to exhaustive tests on other lines before it is placed in service.

Output of gold in Saskatchewan during the first half of the year amounted to 20,421 fine ounces (in blister copper and in gold bullion), according to a federal report on the Dominion's mineral production, valued at $422,140. The equalisation exchange amounted to $295,250, making a total in Canadian funds of $717,390.

Placer gold mining in British Columbia during 1937 was reported by 100 operators. Production of gold from alluvial deposits totalled 54,153 crude ounces, and the industry distributed $861,644 in salaries and wages to 618 employees. Consumption of fuel and process supplies amounted to $137,561.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£94	0	0

ANTIMONY.

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Chinese		51	0	0
Crude		37	0	0

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Solid Drawn Tubes	lb.	0	0	11½
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	5

COPPER.

Standard Cash		£42	14	0
Electrolytic		48	0	0
Best Selected		49	5	0
Tough		48	2	6
Sheets		81	2	6
Wire Bars		50	10	0
Ingot Bars		50	10	0
Solid Drawn Tubes	lb.	0	1	0½
Brazed Tubes	,,	0	1	0¼

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum °	,,	0	4	9
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL: 6–8 Carbon, scale 7/6 per unit	,,	23	15	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	1	10	0
Durham	—	1	14	6
Furnace Coke—				
Scotland	—	1	7	6
S. Wales	—	1	7	6
Durham	—	1	4	2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£66	0	0
*Commercial Ingots		49	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—				
Crown Bars		£12	5	0
N.E. Coast—				
Rivets			—	
Best Bars		12	15	0
Crown Bars		12	5	0
Lancashire—				
Crown Bars		12	5	0
Hoops		13	12	6
Midlands—				
Crown Bars		12	5	0
Marked Bars		15	5	0
Unmarked Bars			—	
Nut and Bolt Bars		11	0	0
Gas Strip		13	12	6
S. Yorks.—				
Best Bars		12	5	0
Hoops		13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11½
†Sheet to 10 W.G.	,,	0	1	0
†Wire	,,	0	1	1½
†Rods	,,	0	1	1 25/32
†Tubes	,,	0	1	6 25/32
†Castings	,,	0	1	3

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,, No. 3		5	18	0
N.E. Coast—				
Hæmatite No. 1		6	0	0
Foundry No. 1		5	2	0
,, No. 3		4	19	0
,, No. 4		4	18	0
Silicon Iron			—	
Forge		4	18	0
Midlands—				
N. Staffs. Forge No. 4		4	18	0
,, Foundry No. 3		5	1	0
Northants—				
Foundry No. 1		5	1	6
Forge No. 4		4	17	6
Foundry No. 3		4	18	6
Derbyshire Forge		4	18	0
,, Foundry No. 1		5	4	0
,, Foundry No. 3		5	1	0
West Coast Hæmatite		6	12	0
East ,, ,,		6	11	0

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Aluminium Cuttings		59	0	0
Lead		13	10	0
Heavy Steel—				
S. Wales		3	2	0
Scotland		2	19	0
Cleveland		3	0	0
Cast Iron—				
Midlands		2	15	0
S. Wales		3	2	0
Cleveland		3	12	6
Steel Turnings—				
Cleveland			—	
Midlands		2	0	0
Cast Iron Borings—				
Cleveland			—	
Scotland		1	14	0

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India		14	0	0
Re-melted		11	5	0

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Scotland		£10	10	6
North-East Coast		10	10	6
Midlands		10	10	6
Boiler Plates (Land) Scotland		11	8	0
,, ,, (Marine) ,,			—	
,, ,, (Land), N.E.Coast		11	8	0
,, ,, (Marine) ,,			—	
Angles, Scotland		10	8	0
,, North-East Coast		10	8	0
,, Midlands		10	8	0
Joists		10	8	0
Heavy Rails		9	10	0
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Sheffield—				
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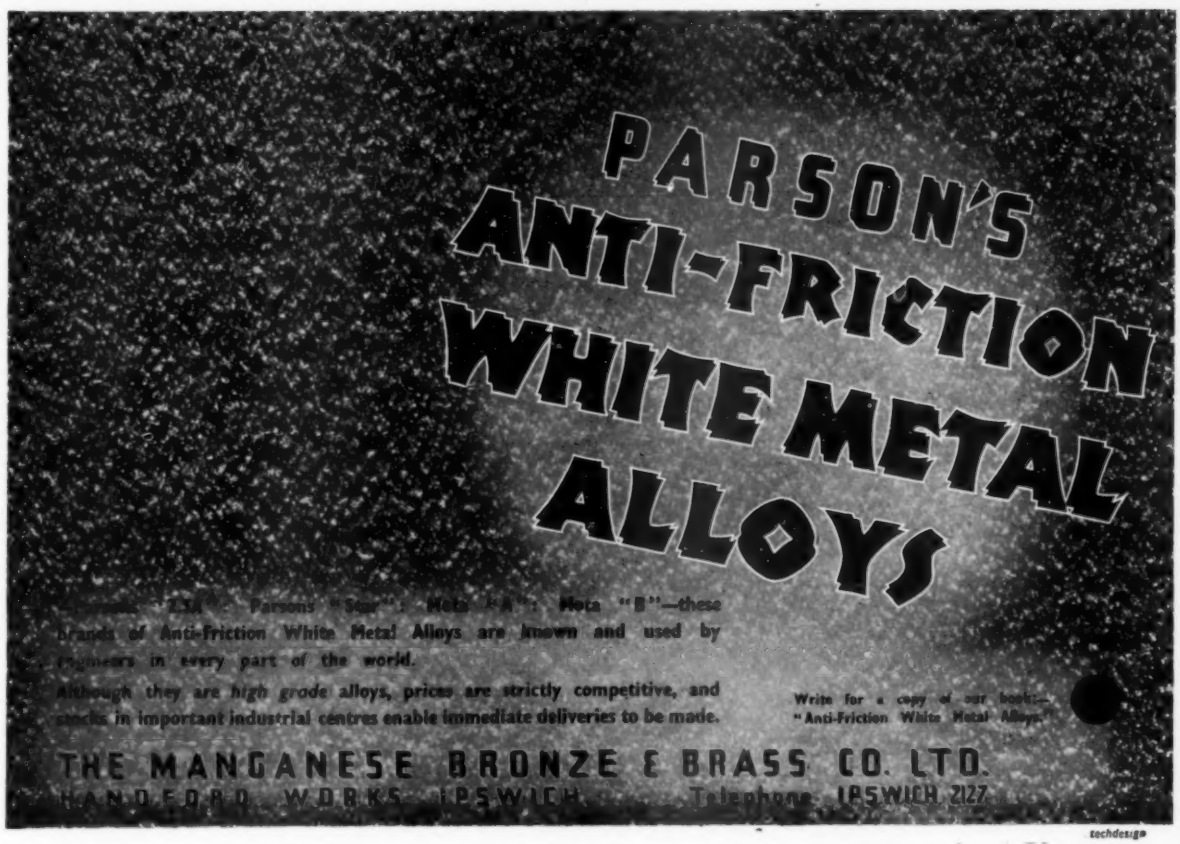
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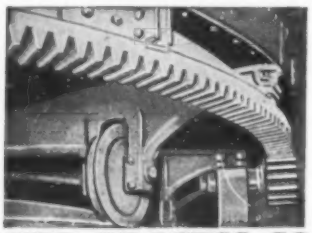

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